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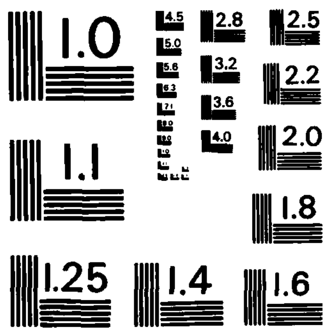

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Preliminary Evaluation of the Basic Experimental Active Beacon Collision Avoidance System (BCAS)

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March 1982

Final Report

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16. Abstract

This data report provides information on the testing of a basic Active Beacon Collision Avoidance System (ABCAS). The system tests were initiated in February of 1980 and were conducted in a test-evaluate-design improvement iterative process. As a result, the data in this report generally is restricted to tests which were conducted after July 13, 1980. This date is considered the point at which the design of the tracking and threat evaluation and resolution software was frozen. The flight program consisted of conducting planned encounters and operational familiarization flights in terminal areas. Two hundred and twenty-five (225) hours of instrumented flight were conducted which included 255 planned encounters and 131 operational and demonstration landings and approaches into 18 major cities. During the test period following July 13, 114 hours of instrumented flight were conducted which included 110 planned encounters and all of the operational and demonstration landings and approaches. During this period of instrumented flight, 23 unplanned encounters were experienced with random targets. Initial evaluations were performed on target acquisition range, computer utilization, track continuity, and advisory verification and appropriateness of planned and unplanned encounters.

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METRIC CONVERSION FACTORS

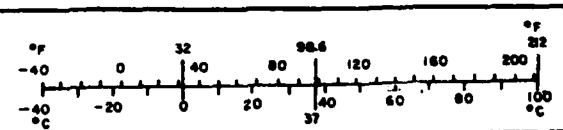
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

PURPOSE.

The purpose of the flight test program was to measure and evaluate the performance of Beacon Collision Avoidance System (BCAS) Experimental Units (BEU) in both test and operational environments. The evaluation report relates measured performance with system requirements as stated in the "Program Test Plan for the Basic Experimental BCAS," dated June 1980.

BACKGROUND.

Though sufficient testing of early engineering models had been performed to demonstrate the technical and economical feasibility of Active BCAS, the early engineering BCAS models had deficiencies which made it difficult to gain the operational experience required to specify characteristics and parameters for National Standard considerations. New BEU's were contracted for in which known deficiencies had been corrected. Two of these systems were supplied to the Federal Aviation Administration (FAA) Technical Center and were used to collect data, gain operational experience, and demonstrate the operational capability of Active BCAS.

DISCUSSION

GENERAL.

This report contains the results of testing conducted on two BEU systems which were designed and fabricated by the Massachussetts Institute of Technology, Lincoln Laboratory and delivered to the Technical Center in January and March 1980. The initial system was delivered with a surveillance (target acquisition and tracking) capability and was tested in this mode. Subsequently, this system was upgraded and, with the second system, contained surveillance, Collision Avoidance System (CAS) tracking, threat detection, and threat resolution capability. The testing of these systems was iterative in that multiple cycles of test, evaluate, and design updates were conducted. As a result of this sequential testing, the data in this report are basically limited to that which reflects software version 6A. This version was delivered in July 1980, and contained the latest CAS tracking parameters and vertical miss distance threat logic features.

Most of the testing prior to July consisted of flying planned encounters in the Washington, D.C., and FAA Technical Center environments. Although some tests prior to July 13, 1980 are included, the majority of tests upon which this report is based were initiated on that date. This testing included 3 weeks of operational familiarization tests conducted in cities which were located in the Eastern, Southern, Western, Central, Northwest, and Rocky Mountain Regions. The testing also consisted of flying encounters in Los Angeles, Washington, D.C., New York, and Technical Center airspace. These planned encounters involved one or two threat aircraft which were either equipped with another BEU, an Air Traffic Control Radar Beacon System (ATCRBS), or Discrete Address Beacon System (DABS) transponder.

The total test program, which was initiated in February 1980, consisted of flying two systems independently or in conjunction with each other on various planned encounter configurations, into terminal areas, and on other project flights on a noninterfering basis. The total system operating time was approximately 225 hours, in which a total of 255 planned encounters were flown. From July 13 through October 14, a total of

110 planned encounters, representing 133 system encounters, were flown. Maneuver advisories were provided in all but five ATCRBS encounters. The advisories which were not provided consisted of one tail-chase and four head-on encounters. Three of the missed advisories occurred at the Technical Center on a single test date, and the other two occurred at Los Angeles on another single test date. Each of the five encounters involved two aircraft; in three of these each of the aircraft had an operating system. In these three cases, one of the systems provided an advisory for each of the three encounters. These five missed advisories may have resulted from equipment failures.

In the total of 225 flight hours, no known false alarms were generated. In addition, 23 random encounters were experienced and, in all cases, advisories were provided.

TEST CONFIGURATIONS.

Throughout the flight test program, a basic group of flight patterns were used for planned encounter missions. These are shown in appendix A. They include two and three aircraft tail-chases, head-ons, vertical and horizontal closures, etc. Combinations of the patterns were flown in the Los Angeles, Washington, D.C., New York City, and FAA Technical Center areas.

In addition to planned encounter flights, operational flights were conducted which included flying in terminal areas. Most of this flying was done following normal traffic patterns. Low approaches and touch-and-go landings were flown at the 33 airports visited.

Also shown in appendix A is the geographical location and very high frequency omnidirectional radio range and tactical air navigation aids (VORTAC's) over which the encounters were flown in the Washington, D.C., FAA Technical Center, and Los Angeles areas.

TRACKING SYSTEMS.

An Automated Radar Terminal System (ARTS) III was used at the FAA Technical Center and remote facilities for multi-aircraft tracking and environmental studies. ARTS III or IIIA data were collected at the following locations:

FAA Technical Center — Terminal Automated Test Facilities (TATF), Atlantic City Airport, New Jersey

Los Angeles, California

Denver, Colorado

Dallas/Fort Worth, Texas

Washington, D.C.

Kansas City, Missouri

San Francisco, California

Houston, Texas

Seattle, Washington

RESULTS AND ANALYSES

The analyses concentrate on those test results which reflect the system operation subsequent to acquiring targets and establishing surveillance tracks. This consists of establishing ATCRBS and DABS tracks in the CAS logic and, upon determining that the tracked intruder is a threat, issuing a maneuver advisory. Maneuver advisories are displayed on a cockpit located instantaneous vertical speed indicator (IVSI) and are limited to vertical directions. The advisories consist of: climb (C), dive (D), do not

climb (NC), do not dive (ND), limit rate of descent (LD), or limit rate of climb (LC) to 500, 1,000, or 2,000 feet per minute. Specifically, the analyses address CAS track establishment, continuity, and the associated maneuver advisories.

ENCOUNTER COMMAND SUMMARY.

The initial flight test encounter profiles (see appendix A) were flown in the Technical Center airspace and were developed to provide a wide range of head-on and tail-chase encounters, which included aircraft in level, ascending, descending, and turning flight patterns. Subsequently, the test program was expanded to include additional profiles in the Los Angeles, Washington, D.C., and New York areas.

The encounter tests evaluated in this report were initiated in February 1980 and ended on October 14, 1980. These tests utilized a series of software program versions whose capability ranged from surveillance through threat resolution for both ATCRBS and DABS targets. The software program versions represented design progressions and improvements which were dictated, to a large extent, by Lincoln Laboratory and Technical Center flight testing. The progressions and improvements affected performance parameters to the extent that only those encounters which were conducted after July 13, 1980, and which utilized software program versions 6A, 6B, or 6C could be considered for encounter command evaluation. These software program versions included changes to the altitude tracker parameters which influenced advisory determinations.

Various aircraft (see table 1) and equipment configurations were used in these encounters. Two BEU systems were available for testing, and one each was installed in the FAA's Boeing 727 (N-40) and Convair 580 (N-49). Encounters were conducted using combinations of two and three aircraft and included BEU against BEU, BEU against ATCRBS transponders, BEU against DABS transponders, and BEU against BEU and DABS operating simultaneously.

TABLE 1. AIRCRAFT TYPE AND IDENTITIES

Type of Aircraft	Aircraft Identification
Boeing 727	N-40
Convair 580	N-49
Grumman G1	N-47
Cessna 421	
Cessna 421B	N-5

The encounter command data which were generated between July 13 and October 14 are contained in tables 2 through 11. The information in these tables includes the type of encounters, ranges between aircraft at the time of an advisory, range TAU's, equipment configurations, and the most severe advisory associated with each specific encounter. The TAU, measured in seconds, is the warning time to collision with a compensating distance modification (DMOD). It is obtained by calculating the ratio of range minus DMOD to the range rate. The DMOD is a compensation provided for late warnings that would result for turning situations. The system established TAU and DMOD parameters are exhibited in table 2.

TABLE 2. TAU AND DMOD PARAMETERS

Performance Level	TAU (sec)	DMOD (nmi)
5	30	1.0
4	25	0.3
3	20	0.1

The encounter flights conducted since July 13 were flown in Los Angeles, Washington, D.C., New York, and at the Technical Center. They consisted of ATCRBS, DABS, and BEU versus BEU encounters. The evaluation consisted of determining if (1) advisories were provided, (2) were in the proper direction, and (3) if they were timely as indicated by the range TAU. In this analysis a proper maneuver is considered to be one that directs the aircraft away from the intruder.

The Los Angeles flight data were generated by flying head-on, tail-chase, and 45° encounters off of the Seal Beach VORTAC on July 19 and 20 (see appendix A for profiles). The July 19 flights were conducted utilizing the Boeing 727 (N-40) as the BEU-equipped aircraft and the Convair 580 (N-49) as a DABS-equipped aircraft. It is observed in table 3 (July 19) that in each case an advisory was received and was in the desired direction. Three additional encounters were flown on this date but, due to recorder problems, their advisories could not be verified when data were analyzed; however, flight logs indicate that advisories were received and the direction of the advisories were correct. It is additionally noted that TAU values are timely when data are available. In some cases, short TAU's are indicated; however, the data are confounded by data gaps.

TABLE 3. LAX ENCOUNTERS ATCRBS MODE OF DABS — 7/19/80 N-40(1)

Run No. 2(2)	Range at Advisory (nmi)	Range TAU (sec) (5)	Most Severe Advisory (6)
1 - TC	0.3	22.0	C
3 - TC	0.8	21.2(3)	NC
11 - HO	1.5	10.6(3)	ND
11 - HO	3.5	23.1	C
12 - HO	3.3	20.7(3)	C
12 - HO	3.8	23.6	C
13 - HO	3.9	22.6	NC
13 - HO	3.8	23.8	NC
14 - HO	2.8	19.4(3)	NC
10A- MB	0.8	13.6(4)	NC
10B- MA	1.4	19.4(3)	ND
15A- MA	1.1	6.0(4)	ND
15B- MB	1.0	5.5(4)	LC

(1) Target aircraft (N-49) DABS-equipped.

(2) TC = Tail-chase, HO = Head-on, MA = Maneuver N-40 above, MB = Maneuver N-40 below. Three reports missing due to recorder difficulties.

(3) Data gap prior to advisory.

(4) Advisory received upon breaking altitude threshold.

(5) Performance level 4, TAU = 25 seconds. Calculated TAU's based on ATCRBS mode of DABS data.

(6) C = Climb, NC = No climb, ND = No descent, LC = Limit climb.

The experimental DABS transponders replied to both DABS and ATCRBS interrogations. As a result of this characteristic, separate ATCRBS and DABS CAS tracks were generated on a single target aircraft. The July 19 Los Angeles data were generated on N-49 which was used as a target aircraft that was DABS transponder equipped. The data in table 3 are based on ATCRBS replies from the DABS transponder. Evaluation of flight data indicated that DABS CAS track records (see figure B-3 in appendix B for examples of this record) did not exist. The flights in the Los Angeles area presented a system problem relative to real time data recording. Due to the low data transfer rate from the computer to the recorder, the amount of real time data that could be recorded was limited. As a result, selectivity had to be used with respect to the number of different data records that were recorded. During these July 19 flights DABS replies were not recorded and, as a result, investigation into the cause of the loss of DABS track data could not be conducted.

Subsequent testing of DABS transponder replies to interrogations were conducted at the Technical Center. It was established that the power output at the Convair 580 antenna met specifications (250 watts). In addition, bench checks could not establish any DABS transponder functioning deficiencies.

Subsequent to the Los Angeles flights, DABS encounters were conducted in the Technical Center and New York areas to evaluate DABS performance. The August 26 and October 8 Technical Center DABS data appearing in tables 4 and 5 indicate that DABS tracks were developed in all cases, and advisories were provided which directed the BEU equipped aircraft away from the intruder. In all cases, where applicable, range TAU's were timely.

The October 8 data in table 5 represents information obtained from two aircraft pairs. The flights were conducted using N-49 and N-47 as one pair and N-49 and Lincoln Laboratory's 421 and BEU as the other.

For those encounters involving the N-49 and C-421 aircraft pair, timely advisories in the proper direction were provided in all cases. A statistical test of TAU means and variances resulting from the N-49/N-47 and N-49/C-421 BEU systems indicate that there is no difference in the performance due to the aircraft pairs.

TABLE 4. FAA TECHNICAL CENTER DABS ENCOUNTERS — 8/26/80

Run No.	Aircraft BEU	Aircraft Target	Range[1] TAU (sec)	Most Severe[2] Advisory
11	N-40	N-49	23.9	C
12	N-40	N-49	24.1	C
13	N-40	N-49	22.9	D
14	N-40	N-49	23.4	D

(1) Performance level 4, TAU = 25 seconds.

(2) C = Climb, D = Descend.

TABLE 5. FAA TECHNICAL CENTER DABS ENCOUNTERS — 10/8/80[1]

Run No.[8]	Range at Advisory (nmi)	Range[7] TAU (sec)	Most Severe[9] Advisory
11[2]			C
11[2]			C
12[2]			C
12	3.10	22.8	C
13	3.0	22.9	D
13	3.10	22.9	D
14	3.05	23.4	D
14	3.92	23.3	D
47	0.99	6.0[4]	C
48	2.96	23.1	C
49	3.04	23.4	D
50	2.80	23.2	D
135	2.80	21.1[6]	C
136	2.58	23.7	C
137[5]	2.64	23.3	C
138[5]	2.24	23.4	C
90°	1.96	24.1	D
90°	2.26	23.9	D
90°	2.17	23.4	C
90°	2.13	22.3	C
11	2.33	23.4[3]	C
11	2.58	23.3	C
11	2.42	23.2	C
13	2.46	22.7	D
13	2.46	22.6	D
13	2.75	23.0	D

(1) Flight conducted in DABS mode, N-49 and N-47 aircraft.

(2) Data not recoverable. Information based on flight logs.

(3) These last six encounters were conducted with Lincoln Laboratory's 421 aircraft which was BEU-equipped with DABS operating simultaneously. N-49 operating with BEU on.

(4) Solid track. Altitude difference greater than threshold cause of late range TAU.

(5) Aircraft essentially at coaltitude during encounter. No. 137 - alt. = 25 ft. No. 138 - alt. = 6 ft.

(6) Short range TAU due to too great an altitude difference (600 ft).

(7) Performance level 4, TAU = 25 sec.

(8) All head-on encounters except those at 90°.

(9) C = Climb, D = Descent, NC = No climb.

On October 14, DABS encounters were flown in the New York airspace in order to generate data in a fruit and aircraft density environment which was representative of that experienced in the Los Angeles DABS flights. To support fruit and density evaluations, a measure of these two parameters had to be established. Two additional records, numbers (Nos.) 4 and 10 (see appendix B), are available in the BEU recording process and were used to establish a measure of fruit and density. No. 4 record provides a list of each reply that is received by the system every second. These records could contain more than one reply in the same second from the same target. These multiple replies are a result of multipath or response to more than one of the eight interrogations transmitted by the BEU every second. The occurrence of these multiple replies are considered minimal in the present software program and, therefore, their utilization was considered valid in establishing a BEU perceived fruit rate estimate. This fruit rate estimate was calculated in the following manner:

$$\text{BEU Perceived Fruit} = \frac{\text{Replies (No. 4)} - \text{Density (No. 10)}}{\text{(No. of interrogations)} \times \text{(Listening interval)}}$$

No. of interrogations = Eight interrogations transmitted per second

Listening interval = Listening time interval for interrogation replies (250 microseconds per interrogation).

Replies = Total number of replies received in each second

Density = Number of CAS tracks in existence as recorded in type 10 data record (appendix B)

The Technical Center Program Test Plan defines density as the 60-second average number of mode C aircraft within a 10-mile radius of the BEU-equipped aircraft. The density which is utilized in this evaluation is consistent with the preceding definition based on those aircraft that exist in the CAS tracker record (No. 10). The fruit rate estimate used in this report is also based on a 60-second average, but is not limited to a 10-mile radius of the BEU-equipped aircraft.

Based on this method, the estimate of the maximum 60-second average fruit counts in Los Angeles and New York were 29,000 and 18,000, respectively. Maximum 60-second average mode C aircraft densities recorded in Los Angeles and New York were 10 and 12, respectively. The results of 12 head-on and four 90° encounters flown in the New York airspace appear in table 6. In all cases advisories were received, were in a direction to avoid collision, and the TAU's were timely.

Software program versions 6A and 6C were used in the New York flights. Program version 6A, which was used in Los Angeles, was used in 10 of the encounters. Program 6C contained a DABS target acquisition improvement that was introduced after the Los Angeles flights. Program 6A contained a software feature that would cause the system to stop interrogating DABS targets after not receiving replies to previous interrogations. No difference was noted in the performance in the New York tests of the two software program versions.

The ATCRBS data in tables 7 and 8 represent that which were generated when operating BEU's simultaneously on N-40 and N-49 at Los Angeles. In all cases where advisories were received on both aircraft, they complemented each other. A single occurrence of a failure to receive an advisory occurred on each aircraft (run 14 — N-40, run 12 — N-49). The aircraft that received an advisory when the other did not, received one which was in the proper direction. As in the case of the July 19 data (table 3), short TAU's are apparent and, again, are a result of data gaps and no tracks. These data

TABLE 6. NEW YORK DABS ENCOUNTERS — 10/14/80[1]

Run No.[2]	Range at Advisory[3] (nmi)	TAU (sec)	Most Severe Advisory
13	3.28	23.6	D
13	3.39	24.0	D
13	3.47	23.2	D
11	3.48	23.7	C
11	3.07	23.2	C
11	3.34	23.2	C
11	3.44	23.8	C
11	3.28	23.2	C
11	3.17	23.7	C
13	3.56	23.4	D
13	3.21	23.5	D
13	3.84	23.4	D
90°	2.04	23.1	C
90°	2.31	22.4	C
90°	2.40	23.1	D
90°	2.18	23.0	D

(1)The flights were conducted in the DABS mode.
(2)N-40 was BEU-equipped. Target aircraft N-49. All head-on encounters except where noted.
(3)First six encounters with program version 6C and last ten with version 6A. Performance level 4 (TAU = 25 sec).

TABLE 7. LOS ANGELES ATCRBS ENCOUNTERS — 7/20/80 N-40[6]

Run No.[1]	Range at Advisory (nmi)	TAU[7] (sec)	Most Severe[8] Advisory
1 - TC	1.0	22.0[4]	C
1 - TC	0.7	21.8	C
3 - TC	0.8	23.5	NC
3 - TC	0.7	14.5[3]	NC
11 - HO	3.7	23.8	C
11 - HOB	2.3	14.1[4]	NC
12 - HO	3.2	22.9	C
12 - HOB	3.5	23.5	NC
13 - HO	3.7	23.3	C
13 - HO	3.1	19.1	C
14 - HO	3.9	22.7	C
14 - HO	-[2]	-	None
10A- MA	1.6	23.6	C
10B- MB	1.0	12.0[4][5]	NC
15A- MB	0.8	3.5[5]	NC
15B- MA	3.1	22.0	C

(1)TC = Tail-chase, HO = Head-on N-40 above, HOB = Head-on N-40 below, MB = Maneuver N-40 below, MA = Maneuver N-40 above.
(2)Missed advisory.
(3)No track prior to advisory.
(4)Data gap.
(5)Advisory received upon breaking 750 feet altitude threshold.
(6)Target aircraft N-49.
(7)Performance level 4, TAU = 25 seconds.
(8)C = Climb, NC = No climb.

TABLE 8. LOS ANGELES ATCRBS ENCOUNTERS — 7/20/80 N-49[5]

Run No.[1]	Range at Advisory (nmi)	TAU[6] (sec)	Most Severe Advisory[9]
1 - TC	1.1	27.0	D
1 - TC	0.5	14.3[3]	D
3 - TC	0.5	11.7[3]	C
3 - TC	0.8	21.1[4]	C
11 - HO	0.1	0.9[7]	D
11 - HOA	3.7	23.8	ND
12 - HO	[2]		None
12 - HOA	3.6	23.8	ND
13 - HO	0.8	3.2[3]	D
13 - HO	1.2	5.7[3]	D
14 - HO	3.5	20.0[3]	D
14 - HO	3.5	23.5	D
10A- MB	1.2	16.9	NC
10B- MA	0.3	8.1[3][8]	ND
15A- MA	0.9	4.5	ND
15B- MB	1.2	6.6	NC

[1] TC = Tail-chase, HO = Head-on, HOA = Head-on N-49 above, MA = Maneuver N-49 above, MB = Maneuver N-49 below. See appendix A.
[2] Missed advisory.
[3] No track prior to advisory.
[4] Data gap prior to advisory.
[5] Target aircraft N-40.
[6] Performance Level 4, TAU = 25 seconds.
[7] No track, only 1 data point. Track in existence for 6 seconds with 5 seconds of coast. DMOD not included in TAU calculation.
[8] DMOD not included in TAU calculation.
[9] C = Climb, D = Descend, NC = No climb, ND = No descend.

losses have prevented detailed investigations of the Los Angeles test flight tracking performance as well as the occurrence of the short TAU's in the recorded data. It is noted that TAU values, which are free from data gaps and broken tracks, are representative of those appearing in the other data tables where TAU's were timely.

The Washington, D.C., ATCRBS data appearing in table 9 were derived from flying a total of five head-on encounters on 2 different days. The encounters were flown above and below 10,000 feet and are representative of performance levels five and four whose respective TAU's are 30 and 25 seconds. The mean TAU's are 28 and 23.7 seconds, respectively, and the advisories are in the desired direction.

The Technical Center ATCRBS encounter data were generated by flying two and three aircraft encounters on August 14, 26, and September 26.

The August 26 test consisted of flying encounters with both BEU's operating. It is observed in table 10 that N-40

TABLE 9. WASHINGTON, D.C., ATCRBS ENCOUNTERS

Date	Run No.[3]	Range at Advisory (nmi)	TAU (sec)[4]	Most Severe Advisory[5]
9/8/80[1]	13 - HO	2.43	23.9	D
	13 - HO	2.74	23.7	D
	13 - HO	2.68	23.6	D
9/17/80[2]	13 - HO	4.92	28.80	D
	13 - HO	4.65	27.2	D

(1)N-40 BEU equipped. N-5 - Target aircraft.

(2)N-40 BEU equipped. N-47 - Target aircraft.

(3)Head-on all targets above BCAS aircraft.

(4)Performance level 4 on 9/8/80, TAU = 25 seconds.
Performance level 5 on 9/17/80, TAU = 30 seconds.

(5)D = Descend.

TABLE 10. FAA TECHNICAL CENTER ATCRBS ENCOUNTERS

		TAU (sec)[6]		Most Severe Advisory[8]		Aircraft	
Date	Run No.[1]	N-40	N-49	N-40	N-49	BEU	Target
8/26/80	11	(2)	(2)			N-40,N-49	
	12	1.8	23.2	ND	NC	N-40,N-49	
	13	(3)				N-40,N-49	
	14	(4)	23.2		C	N-40,N-49	
	21	(5)	2.7		D	N-40,N-49	
8/14/80[7]	11				C	N-49	N-47
	13				D	N-49	N-47

(1)All head-on encounters except 21.

(2)No advisory on N-40 due to no track. No advisory on N-49 due to system being down.

(3)No advisory on N-40 due to no track. No advisory on N-49 due to BEU system problems.

(4)No advisory on N-40 due to transmitter being turned off.

(5)No advisory on N-40 due to no track. Short range TAU due to altitude separation near threshold of 750 feet.

(6)Performance level 4, TAU = 25 sec.

(7)Verification data unavailable. Information obtained from flight logs.

(8)C = Climb, D = Descend, NC = No climb, ND = No descend.

did not receive an advisory in three out of four encounters in which data were considered valid. For the N-49 valid encounters listed in table 10, the advisories, which were range dependent, exhibited timely range TAU's. The single case of the 2.7 second range TAU was a result of an altitude separation of 750 feet, which is the threshold which must be broken before an advisory can be generated. In the single case where advisories were received on both N-40 and N-49, they were complementary.

In one of the three cases that N-40 did not provide advisories, the N-49 BEU was operating and provided advisories in the proper direction. Although the cause of the poor performance of the N-40 BEU could not be established, it is recognized that this was an uncharacteristic performance for the BEU in the Technical Center airspace. When the ATCRBS difficulties were observed during the testing, the N-49 aircraft was reconfigured in the DABS mode in table 4 and the performance was excellent.

Subsequent to these flights, ATCRBS tests were conducted at the Technical Center on September 26, (table 11). On this date, 16 head-on and 4 tail-chase encounters were conducted utilizing three aircraft (see appendix A).

The purpose of these flights was to test the BEU system against multiple aircraft encounters and to attempt to isolate previous N-40 and N-49 tracking difficulties. The results of the encounters indicate that the lead aircraft was consistently tracked in all cases except one, and received timely advisories in a direction that would separate the aircraft. In the exceptional case, a late advisory of 12.6 seconds was received on the lead aircraft (N-49) which was due to a nonexisting track prior to the time of the advisory. The results of the subsequent encounters with the second aircraft indicate consistent tracking and timely advisories in those cases where range, as distinct from altitude, TAU's were the determining factor.

In two cases (see note 8 in table 11) the advisories received in resolution of the encounters with the second aircraft were in a direction that would send the BEU-equipped aircraft through the altitude of the threat aircraft. The present threat and resolution logic will provide advisories which will send a BEU aircraft through the threat's altitude, if it is determined that the greatest separation of the aircraft would be achieved by this type of maneuver. In run No. 178, the BEU aircraft was descending at a rate of approximately 1,700 feet per minute at the time of the advisory to descend through the intruder's altitude. Initial evaluation indicates a projected altitude separation of approximately 700 feet. In run No. 160, the BEU aircraft was ascending at a rate of approximately 1,800 feet per second at the time of the advisory to climb through the intruder's altitude. Initial evaluation indicates a projected altitude separation of approximately 600 feet.

All valid ATCRBS and DABS data generated in the Washington, D.C., New York, and Technical Center encounters were evaluated with respect to their TAU performance (see table 12). The Los Angeles data were not included due to uncertainties associated with data recording and poor N-40 and N-49 tracking. Frequency histograms of the ATCRBS and DABS range TAU's for performance level 4 appear in figures 1 and 2. The data upon which the frequency histograms were established were tested to determine if an assumption of the data being represented by a normal distribution could be rejected. This "W" test, developed by Shapiro and Wilk, is a method of establishing if an assumed normal distribution model is inadequate. The test indicated that the assumed normal model was not inadequate and, therefore, the data were statistically tested and estimated

TABLE 11. FAA TECHNICAL CENTER ATCRBS ENCOUNTERS — 9/26/80

Run No.(1)(7)	Range at Advisory (nmi) 1st	Range at Advisory (nmi) 2nd	TAU (sec)(2)(6) 1st	TAU (sec)(2)(6) 2nd	Most Severe(2) Advisory 1st	Most Severe(2) Advisory 2nd	Antenna(5) Locations N-49	Antenna(5) Locations N-47
177	3.44		x23.3	(3)	D		B	B
178	3.45	3.31	x24.0	21.9	D	C	B	B
177	3.32	3.35	x23.0	23.0	D	C	T	B
178(8)	3.31	3.37	x23.4	24.3	D	D	T	B
178*	3.35	3.10	x23.4	21.6	D	C	D	B
178*	3.43	3.33	x23.8	22.9	D	ND/NC	D	B
177*	3.63	3.10	23.9	x23.2	D	ND	D	B
177*	3.03	3.06	21.7	x23.9	D	ND	D	B
177	3.23	3.20	21.3	x23.3	NC	C	T	B
178	2.47	3.18	17.6	x23.8	D	ND	T	B
177	3.44	3.36	22.4	x23.0	D	C	B	B
178	3.43	3.48	22.9	x24.3	NC	ND	B	B
179	3.10	2.74	23.2	x21.1	C	D	B	B
180	2.22	1.81	15.8	x12.6(4)	C	NC	B	B
179	2.91		x23.4	(3)	ND		B	B
180	3.14	1.75	x22.9	11.1	ND	D	B	B
157	1.13	1.07	x22.8	24.9	D	C	B	B
158	0.86	1.25	12.1	x23.3	D	ND	B	B
159	1.01		x21.5	(3)	ND		B	B
160(8)	1.30	1.25	21.9	x22.6	C	ND	B	B

(1) Three aircraft encounters: N-40, N-49, and N-47. N-40 as BEU aircraft at all times. N-49 also as BEU aircraft for those with * data not presently available.

(2) 1st = initial encounter, 2nd = subsequent encounter, x indicates first encounter. C = Climb, D = Descend, NC = No climb, ND = No descend.

(3) Did not break altitude threshold on 2nd aircraft.

(4) Aircraft not in track prior to advisory.

(5) B = Bottom, T = Top, D = Diversity.

(6) Sensitivity level 4, TAU = 25 sec.

(7) All head-on encounters except last four which are tail-chases.

(8) BEU-equipped aircraft directed through intruder's altitude.

TABLE 12. ATCRBS AND DABS RANGE TAU SUMMARY

Date (1980)	Area of Flight	Aircraft Combinations	Advisory Statistics: Mean (x)(1) A	Mean (x)(1) D	Standard Deviations(s)(1) A	Standard Deviations(s)(1) D	No. of Encounters Considered	Performance Level
9/8	Wash., D.C.	N-40B - N-5	23.7		0.15		3	4
9/17	Wash., D.C.	N-40B - N-47	28.0				2	5
10/14	New York	N-40B - N-49		23.3		0.38	16	4
8/26	FAA Tech Ctr.	N-40B - N-49B		23.6		0.54	4	4
8/26	FAA Tech Ctr.	N-49B - N-40B	23.3				2	4
9/26	FAA Tech Ctr.	N-40B - N-49B-N-47	23.4		0.46		17	4
10/8	FAA Tech Ctr.	N-49B - N-47		23.3		0.45	15	4
10/8	FAA Tech Ctr.	N-49B - 421B		23.0		0.33	6	4

(1) A = ATCRBS targets, D = DABS targets.

accordingly. Table 13, which provides the results of the TAU statistics, indicates no differences in the ATCRBS and DABS range TAU performance, and provides estimates on individual range TAU's.

An encounter advisory summary is presented in table 14 and indicates the results of the individual encounter advisories. This summary is a compilation of BEU data verification and flight logs. In those cases where data verification could not be accomplished, the flight log information was considered acceptable proof that an advisory had been received.

FLIGHT TIME AND FALSE ALARMS.

Testing of the first BEU at the Technical Center took place in February 1980. From that initial period until October 14, 1980, flight hours were logged by flying encounters, conducting an operational flight program, participating in other project flights on a noninterfering basis, conducting flights in association with Lincoln Laboratory, and conducting project familiarization flights.

In table 15, the following can be observed:

Encounter Flights — 255 individual encounter flights in 21 days for a total of 49 hours.

Operational Tour — 17 individual flying days into 33 cities and airports for a total of 75 hours.

Other Flights — 21 individual flights for a total of 101 hours.

These three flight categories total up to 225 hours of BEU system operation. In these hours of flying, two major and several minor BEU system failures occurred. The two major system failures were attributable to the radiofrequency unit. One failure occurred in each system. In both cases it was the whisper-shout attenuator. This type of failure renders the system inoperable for valid project data gathering. The minor system failures were almost wholly related to the Quantex data recorders and their controlling software. These failures are not considered major in that they simply cause data losses and introduce difficulties into the data analysis.

During these 225 flight hours a total of 23 random target advisories were received and evaluated (see Target of Opportunity Evaluation). These evaluations consisted of comparing information contained in detailed flight logs, pilot observations, and BEU track and advisory tape recorded data. In some instances, recording problems prevented BEU verification of the advisories; however, visual sightings supported the existence of an intruder. In all of the investigated advisories, it was established that no advisories were generated on false targets by the BEU system.

PROCESSOR LOADING.

Active BCAS operation is designed to degrade gracefully in high density and high fruit environments. One of the considerations, relative to fruit and density, is their effect on processor loading. Block No. 1 data records (see appendix B), which are recorded during BEU operation, contain a measure of processor loading called last idle. Last idle is a record of the fraction of the time that the central processing unit (CPU) was idle during each second.

In order to provide a spread of fruit and mode C aircraft track density levels, Los Angeles (7/19 and 7/20), Washington, D.C. (9/8), and Technical Center (9/26) data were included in the analysis. Figures 3 through 10 are illustrations of maximum 60-second average fruit and track densities that were experienced in the above

TABLE 13. RANGE TAU STATISTICS — PERFORMANCE LEVEL 4

Estimate[1]	MODE[3] DABS	ATCRBS
Sample Size	41	22
Mean (x)	23.3 sec	23.4 sec
Standard Deviation(s)	0.42 sec	0.43 sec
Tolerance Limits[2]		
Upper	24.6 sec	24.9 sec
Lower	22.0 sec	21.9 sec

(1)Statistics do not include 21.1 and 21.5 sec occurrences on 9/26/80 in table 11.

(2)With 95 percent confidence we can expect the individual TAU's to be within these limits 99 percent of the time.

(3)Statistical tests (F&T) at the .05 level of significance indicates no difference in the ATCRBS and DABS TAU performance data.

TABLE 14. SYSTEM ENCOUNTER ADVISORY SUMMARY

Encounter[1] Type 1	Number of Encounters	Direction of Command
Tail-chase - Aircraft above	11	Ascend[2]
Tail-chase - Aircraft below	9	Descend[3]
Head-on - Aircraft above	52	Ascend[4]
Head-on - Aircraft below	53	Descend[5]
90° - Aircraft above	4	Ascend
90° - Aircraft below	4	Descend
45° - Aircraft above	6	Ascend
45° - Aircraft below	6	Descend

(1)Aircraft is BEU equipped.

(2)One miss on 8/26.

(3)One climb through intruder's altitude. Approximate projected vertical miss distance is 700 feet.

(4)One no climb, no descend. One miss on 7/20. One miss on 8/26. One descend through intruder's altitude. Approximate projected vertical miss distance is 600 feet.

(5)One miss on 7/20. One miss on 8/26.

TABLE 15. TOTAL FLIGHT HOURS

	Encounters				Operational Tour[1]				
Date	No. Hours	No. Runs	No. A/C	Date	No. Hours	No. Cities	No. Airports	A/C
2/12/80	1:10	3	2	7/13/80	2:45	1	1	N-40
2/13/80	2:10	9	2	7/14/80	5:00	2	2	N-40
3/19/80	2:30	14	2	7/15/80	4:15	1	1	N-40
3/24/80	3:00	18	2	7/16/80	3:00	1	1	N-40
3/26/80	2:20	17	2	7/16/80	10:30	3	3	N-49
4/8/80	2:15	11	2	7/17/80	3:30	2	2	N-40
4/29/80	1:50	6	2	7/14/80	0:25	1	1	N-49
5/23/80	1:35	6	2	7/18/80	2:00	1	1	N-40
6/3/80	1:50	8	2	7/20/80	3:30	1	1	N-49
6/6/80	2:20	8	2	7/21/80	3:30	1	1	N-49
6/28/80	2:20	15	2	7/22/80	2:00	2	2	N-40
7/2/80	4:10	30	2	7/23/80	4:00	2	2	N-40
7/19/80	3:00	16	2	7/24/80	5:35	4	4	N-40
7/20/80	2:40X2	16	2	7/25/80	2:10	2	2	N-40
8/14/80	0:30	2	2	7/26/80	1:10	2	2	N-40
8/26/80	1:35X2	9	2	8/28/80	4:40	1	1	N-40
9/8/80	0:30	3	2	8/29/80	6:40	2	3	N-40
9/17/80	1:00	2	2	9/2/80	5:05	1	1	N-40
9/26/80	2:30	20	3	9/3/80	5:05	3	3	N-40
10/8/80	3:00	26	2					
10/14/80	2:30	16	2					
TOTAL 21 days	49	255		20 Days	75	32	32	

Other[2]

Date	No. Days	No. Hours	Type	Date	No. Days	No. Hours	Type
2/15/80	1	1:00	P/B	7/7/80	4	26:00	P/B
2/27/80	1	1:10	P/B	8/4/80	3	7:20	P/B
3/13/80	1	1:00	L/L	8/19/80	1	0:25	FAM
4/14/80	5	21:20	P/B	8/19/80	1	2:30	L/L
4/24/80	1	2:10	FAM	9/5/80	1	0:45	FAM
4/25/80	1	1:45	FAM	9/11/80	1	2:35	P/B
5/5/80	4	6:00	L/L	9/12/80	1	2:10	FAM
5/12/80	3	10:45	P/B	9/16/80	1	1:50	FAM
6/4/80	1	1:10	P/B	9/25/80	1	1:45	DABS Test
6/5/80	1	2:55	P/B				
6/11/80	1	4:10	P/B	Events	Days	Hours	
7/1/80	1	1:50	FAM	TOTAL 21	35	101	

[1]The operational cities and airports, in some cases, reflect repetitive flights to some locations.

[2]Flights include operating the BEU simultaneously with other projects. P/B = Piggyback, L/L = Lincoln Lab, FAM = Familiarization.

three areas. The maximum values from each graph are listed in table 16. Significant gaps appearing in the curves are attributable to the lack of recorded data in the interval (see figure 5 for typical examples).

It can be observed that the average number of tracked aircraft within a 10-mile radius of the BEU-equipped aircraft is similar in all areas. However, the fruit in Los Angeles is more than twice that in Washington, D.C., or the Technical Center. This probably being due to the large number of general aviation aircraft flying in the Los Angeles area as compared to the others, and to the greater number of ground interrogators located in the Los Angeles Basin.

The present analysis consisted of an attempt to establish simple regression relationships between fruit and density versus idle time at all areas of consideration. The graphs of these relationships and histograms of the idle time appear in figures 11 through 23. Table 17 contains the results of the regression analyses.

Linear regression is an attempt to establish a straight line relationship between two variables. R^2 is one measure of how well this relationship is established. Values of R^2 less than 0.4 will generally indicate that a low degree of correlation exists between the variables and that the relationship should not be described linearly. Although, in table 17 only two out of the eight R^2 values are favorable relative to linear relationships, a few generalizations can be made by observing the figures 11 through 23. The Los Angeles fruit and density versus idle time plots are more randomly distributed in comparison to the Washington, D.C., and FAA Technical Center plots which appear to have two distinct data groups. A linear regression applied to the upper group of the Washington data resulted in a marginal relationship, as exhibited by an R^2 of 0.49 (see figure 18).

TABLE 16. MAXIMUM 60-SECOND AVERAGE FRUIT AND DENSITY

Area	Date (1980)	Maximum 60-Second Average Fruit(1)	Maximum 60-Second Average Density(2)
Los Angeles	7/19	24,000	9
Los Angeles	7/20(3)	22,800	10
Washington, D.C.	9/8	10,400	11
FAA Tech Center	9/26	10,300	9

(1)Average number of replies per second averaged over 60 seconds.
(2)Average number of tracked aircraft in each 1-second scan averaged over 60 seconds.
(3)Data from N-40.

TABLE 17. AVERAGES AND LINEAR REGRESSION OF FRUIT, TRACK DENSITY, AND IDLE TIME

Area	Date (1980)	R^2_D	R^2_F	Average Fruit	Average Track Density	Average Idle Time
Los Angeles	7/19	0.13	0.97	18078	5.10	0.643
Los Angeles	7/20	0.45	0.65	12389	4.28	0.681
Washington, D.C.	9/8	0.35	0.28	6302	5.78	0.677
FAA Tech Center	9/26	0.23	0.24	5744	4.27	0.708

The two distinct data groups that appear in figures 17, 19, 21, and 22 are separated by approximately 0.1 second. The idle time, which is contained in message type 1 in figure B-1, is accumulated by an idle counter in 1-millisecond increments and is assigned the lowest priority in the BCAS system. Message type one is output once a second, at the end of each second. Other data collected during the following second is placed in another 512 word buffer. It is crucial to note that 1 second of data may fill some portion of a buffer or more than one buffer. The BEU has three such buffers. When a buffer is filled, an interrupt is generated and the data remaining are placed in the next buffer. This interrupt results in the filled buffer being emptied. While this buffer is being emptied, the next second's data are being collected and the idle time for this second is being counted. Its decrease in idle time reflects the overhead associated with the output operation. The emptying of the filled buffer (to the quantex tape drive) is done in a software module called "IQTO." The processing in this module is such that approximately 100 microseconds is required to transfer one byte. Since each buffer contains 1,024 bytes, it takes approximately 0.1 second to be emptied. The two data groups appearing in the Washington and Technical Center regressions are a result of 1-second periods when buffers were emptied or not emptied.

The Los Angeles regressions, which appear in figures 11, 12, 14, and 15 do not indicate these pronounced data groupings because the output buffers were constantly overflowing due to the large amount of data being generated in Los Angeles. As a result of this almost constant buffer overflow, most seconds contained periods when buffers were being emptied and resulted in more constant idle times.

Despite the lack of consistency in establishing linear regression relationships, it can be observed that downward trends (negative slopes) in available idle time result with increasing fruits and densities. In addition, it can be observed in table 17 that much computer idle time remains in the BEU.

ACQUISITION RANGE.

Initiation of surveillance tracks and, subsequently, CAS tracks are dependent upon decoding altitude replies in response to BEU interrogations. Surveillance tracks are established upon decoding and correlation of four consecutive range and altitude replies. CAS tracks are dependent upon the establishment of surveillance tracks and require range and altitude correlation in at least two out of three consecutive replies. Higher levels of fruit and track density could affect these consecutive correlations and, subsequently, the range at which targets could be acquired. In an attempt to establish relationships between fruit, track density, and acquisition range the data from Los Angeles and Atlantic City were analyzed using simple regression techniques. Due to the lack of a sufficient quantity of data, an intermediate fruit area such as Washington, D.C., was not included. Mean values were calculated in order to provide a basis for generalized comparisons.

As indicated in the case of idle time versus fruit and density, an R^2 value less than 0.4 indicates that a low degree of correlation exists between the variables. The types of simple regression relationships that were attempted and their typical results are indicated in figure 24 for the July 20, 1980, Los Angeles data. It can be observed in figure 24 that all regressions possess R^2 values that are indicative of an inability to describe the acquisition range versus fruit and density by these

simple regression relationships. These results were generally typical of all the analyses and, therefore, only the linear regression relationships of $Y = A+B*X$ are included in figures 25 through 38.

These figures are based on the acquisition range, fruit, and density data that appear in tables 18 through 22. In only one case that of the DABS density plot of October 4 (figure 26), is there an indication that a correlation exists ($R = 0.87$). In all other cases, the results are marginal or indicate no simple correlation exists for the ±30-second averages about the acquisition time for fruit and track density versus acquisition range. A generalized observation from figures 25 through 38 is that acquisition range, in many cases, decreases with increases in fruit and density.

Since virtually no simple correlations were established, averages ($\bar{x}$) were calculated to provide a basis for general comparisons. As previously noted, no DABS tracks were established in Los Angeles on July 19; however, as noted in tables 18 and 19, tracks were established from ATCRBS replies received from the DABS transponder. These replies, which were acquired at an average range of 10.4 nautical miles (nmi), are approximately twice the range of the ATCRBS reply acquisition range on July 20. It should be noted that N-49, when using the DABS transponder, is operating in a diversity mode in which top and bottom antennas are used. When N-49 is operating with the aircraft ATCRBS transponder it is using a bottom antenna. The ATCRBS average acquisition ranges on July 20 (table 18) indicate an approximate 2-mile difference in favor of N-40 tracking N-49 (5.8 versus 3.5). The average fruit level seen by N-49 is 6,000 replies/second greater than that seen by N-40.. The run-by-run results for Los Angeles encounters are shown in table 18.

Tables 18 and 20 contain Washington, D.C., flight data from June 28 and September 8, 1980. Although the June 28 data are prior to the July 13 data report initiation date, it is included to provide an additional fruit level. Acquisition range of ATCRBS targets was not affected by the version 6 software program. It can be observed in table 18 that, initially, no difference exists between the ATCRBS and ATCRBS/DABS acquisition ranges (11.8 versus 11.4) on June 8. The average ATCRBS acquisition range on September 8 is approximately 1-3/4 nmi less than on June 28. It should be noted from table 20, that the number of encounters is small and the averages are affected accordingly.

Table 21 indicates that software program versions 6A and 6C were used during the New York flights. The acquisition range for DABS tracks are equal for both program versions. . Since no change in program version 6C was made to improve ATCRBS performance, the 4-mile average acquisition range improvement of ATCRBS tracks (11.9 versus 8.3) was due to other factors.

The ATCRBS acquisition ranges for the three aircraft combinations on September 26 appear in tables 18 and 22. From table 18, it is observed that the N-40 and N-49 average acquisition is approximately 1.5 nmi less than the other aircraft combinations.

On October 8, 1980, DABS encounters were conducted utilizing N-49/N-47 and N-49/421 aircraft combinations. The data in tables 18 and 23 indicate minimal average differences in DABS (10.1 versus 9.2) and ATCRBS mode of DABS (12.0 versus 12.3) acquisition ranges between the two.

Except in the case of the July 20 Los Angeles data (table 17), the acquisition ranges are in excess of 8 nmi. Based on the flight parameters experienced in these flights (maximum closing range

TABLE 18. ACQUISITION RANGE AVERAGE PERFORMANCE

Area	Mean ($\bar{x}$) Date (1980)	Aircraft[1]	Average[2] Acquisition Range (nmi)	Fruit[4]	Density[5]	No. of Encounters (N)
Los Angeles	7/19	N-40 - N-49	10.4A-D	17,773	4.8	11
	7/20	N-40 - N-49	5.8A	13,491	4.4	11
	7/20	N-49 - N-40	3.5A	19,924	4.7	10
Washington, D.C.	6/28	N-49 - N-47	11.8A	9,125	4.2	4
			11.4A-D	12,250	5.5	2
	9/8	N-40 - N-5	10.1A	3,714	2.7	3
New York[3]	10/14	N-40 - N-49	8.3A-D			10
			11.9A-D			6
			11.2D			10
			11.2D			6
Atlantic City	9/26	N-40 - N-49	11.0A	5,627	3.9	15
	9/26	N-49 - N-40	12.9A	3,125	4.0	4
	9/26	N-40 - N-47	12.5A	5,338	3.8	16
	10/8	N-49 - N-47	10.1D	3,176	3.1	17
	10/8	N-49 - 421	9.2D	3,183	4.2	6
	10/8	N-49 - N-47	12.0A-D	3,264	2.6	17
	10/8	N-49 - 421	12.3A-D	3,667	3.2	6

(1)The data provided by BEU on the first aircraft.

(2)A = ATCRBS, D = DABS, A-D = ATCRBS replies from DABS transponder.

(3)Fruit and track density data presently unavailable.

(4)Average of ±30-second averages about the acquisition time for fruit rate estimates as described on page 7 of this report

(5)Average of 60-second averages of the number of CAS tracks within a 10-mile radius of the BCAS aircraft.

TABLE 19. LOS ANGELES, ACQUISITION RANGE — FRUIT — DENSITY

Date (1980)	Encounter[2] Type	Acquisition Range (nmi)	Fruit[3]	Density[4]
7/20 (N-40)[1]	HOA	8.2	11,800	5
	HOB	6.4	13,600	4
	HOA	6.4	9,300	5
	HOB	2.2	12,000	3
	HOB	6.4	6,500	4
	HOB	8.3	12,300	5
	HOB	5.2	12,600	4
	MA	4.6	17,100	6
	MB	3.4	16,700	6
	MB	3.5	19,500	4
	MA	12.8	17,000	3
7/20 (N-49)[1]	HOA	6.3	16,800	5
	HOA	4.3	16,200	3
	HOB	6.5	12,364	5
	HOB	0.9	14,111	5
	HOB	7.8	17,007	4
	HOB	1.3	15,485	4
	MB	4.5	26,836	7
	MA	1.2	28,981	4
	MA	1.3	25,682	5
	MB	1.0	25,833	5
7/19 (N-40)[1]	HOA	11.4	16,000	6
	HOA	6.0	20,900	6
	HOA	11.4	16,400	6
	HOA	12.5	19,200	5
	HOB	5.3	18,800	4
	HOB	12.7	17,800	4
	HOB	11.2	15,100	3
	MB	11.2	10,500	5
	MA	9.8	18,700	5
	MA	11.9	21,900	5
	MB	11.1	20,200	4

(1)Designated aircraft BEU-equipped.

(2)HOA = head-on BEU-equipped aircraft above. HOB = head-on BEU-equipped aircraft below. MA = 45° BEU aircraft descending from above targe. MB = 45° BEU aircraft ascending from below target.

(3)±30-second average, about the acquisition time, for fruit rate estimate as described on page 7.

(4)60-second average of the number of CAS tracks within a 10-mile radius of the BCAS aircraft.

TABLE 20. WASHINGTON, D.C., AQUISITION RANGE — FRUIT — DENSITY

Date (1980)	Target[1] Mode	Aircraft	Acquisition Range (nmi)	Fruit[2]	Density[3]
6/28	A	N-49 - N-47	12.6	8,200	4
	A		13.4	6,400	2
	A		10.9	11,400	3
	A		10.5	10,500	8
	A-D		11.36	15,000	6
	A-D		11.36	9,500	5
9/8	A	N-40 - N-5	12.0	3,077	2
	A		10.4	3,523	3
	A		7.9	4,541	3

(1) A = ATCRBS, A-D = ATCRBS mode of DABS.

(2) ±30-second average, about the acquisition time, for fruit rate estimate as described on page 7.

(3) 60-second average of the number of CAS tracks within a 10-mile radius of the BCAS aircraft.

TABLE 21. NEW YORK ACQUISITION RANGE DATA, OCTOBER 14, 1980[1]

ATCRBS Acquisition Range (nmi)	Encounter[2] Type	DABS Acquisition Range (nmi)	Software Program Version
9.7	HOB	12.5	6A
9.4	HOB	11.8	6A
8.9	HOB	12.0	6A
3.9	HOA	9.1	6A
8.9	HOA	11.8	6A
7.2	HOA	11.7	6A
8.8	HOA	8.6	6A
9.8	HOA	9.7	6A
7.2	HOA	11.8	6A
9.1	HOB	12.5	6A
12.8	HOB	11.2	6C
13.2	HOB	11.6	6C
11.2	90°A	11.3	6C
7.6	90°A	10.5	6C
13.2	90°B	10.9	6C
13.3	90°B	11.8	6C

(1) Aircraft N-40 and N-49. Fruit and density estimates not presently available.

(2) HOB: head-on, BCAS aircraft above. HOA: head-on, BCAS aircraft below. 90°A: BCAS aircraft above. 90°B: BCAS aircraft below.

TABLE 22. ATLANTIC CITY, N.J., 9/26/80 ATCRBS ACQUISITION RANGE — FRUIT — DENSITY

Aircraft Combination(1)	Encounter(2) Type	Acquisition Range (nmi)	Fruit(3)	Density(4)
N-40 - N-49	HO-177	13.2	5,000	3
	HO-178	12.5	5,500	5
	HO-177	10.0	5,700	2
	HO-178	11.4	7,700	4
	HO-178	8.5	7,300	5
	HO-178	9.0	6,300	6
	HO-177	13.4	4,000	1
	HO-177	13.0	5,000	5
	HO-177	10.8	6,200	4
	HO-178	12.3	4,700	2
	HO-177	10.3	4,800	3
	HO-178	9.1	5,000	5
	HO-179	12.9	3,500	3
	HO-179	7.8	7,400	6
	HO-180	10.5	6,300	5
N-49 - N-40	HO-178	13.2	3,100	5
	HO-178	13.4	3,000	4
	HO-177	12.0	4,400	4
	HO-177	12.9	2,000	3
N-40 - N-47	HO-177	13.4	4,500	3
	HO-178	12.2	5,200	5
	HO-177	13.3	6,100	3
	HO-178	13.4	5,200	2
	HO-178	13.1	6,900	4
	HO-178	12.2	4,300	4
	HO-177	13.4	3,600	3
	HO-177	10.4	6,000	6
	HO-177	13.4	6,100	4
	HO-178	10.3	5,900	2
	HO-177	13.3	4,900	3
	HO-178	11.9	5,000	5
	HO-179	12.8	3,900	3
	HO-180	11.4	6,600	6
	HO-179	13.3	5,800	3
	HO-180	12.3	5,400	4

(1)The data provided by BEU on the first aircraft.

(2)HO = head-on, see patterns in appendix A.

(3)±30-second average, about the acquisition time, for fruit rate estimate as described on page 7.

(4)60-second average of the number of CAS tracks within a 10-mile radius of the BCAS aircraft.

TABLE 23. ATLANTIC CITY, N.J. 10/8/80 DABS AND ATCRBS MODE OF DABS ACQUISITION RANGE — FRUIT — DENSITY

	DABS			ATCRBS MODE OF DABS		
Aircraft(1) Combination	Acquisition Range (nmi)	Fruit(2)	Density(3)	Acquisition Range (nmi)	Fruit(2)	Density(3)
N-49 - N-47	10.0	3,200	4	11.2	3,400	3
	12.4	2,200	2	12.9	2,300	2
	9.6	5,000	2	12.9	4,600	1
	10.6	2,400	5	12.7	2,500	4
	9.5	4,000	5	13.2	3,300	5
	7.8	1,900	4	13.1	2,400	2
	6.1	2,300	3	12.0	3,300	2
	11.9	2,300	2	12.2	1,500	2
	9.8	3,700	4	12.4	4,000	3
	11.1	2,900	4	12.1	3,200	4
	10.7	4,100	3	11.8	4,100	3
	10.3	3,500	2	12.9	3,400	1
	8.7	4,600	4	10.6	5,100	3
	11.2	3,700	2	12.6	3,300	2
	11.2	4,500	4	9.7	4,100	5
	11.5	2,100	1	11.7	2,100	1
	10.1	3,000	2	10.6	2,900	2
	11.3	2,700	1	13.6	2,700	1
	11.4	3,800	5	13.1	4,100	4
	12.0	2,600	2	12.2	2,600	2
	7.5	4,200	7	11.0	4,400	6
	7.3	2,200	5	11.4	3,700	3
	6.0	3,600	5	12.5	4,500	3

(1)The data provided by BEU on the first aircraft.

(2)±30-second average, about the acquisition time, for fruit rate estimate as described on page 7.

(3)60-second average of the number of CAS tracks within a 10-mile radius of the BCAS aircraft.

rate of approximately 500 knots), the acquisition ranges experienced in all flight areas are generally in excess of those needed to provide adequate advisory times when track continuity exists.

TRACK CONTINUITY.

In order to provide the required advisory within the time period (TAU) corresponding to system performance levels, the Active BCAS must provide continuous tracks. The BEU system updates its alpha-beta range and altitude trackers each second whether or not an altitude reply is received in the clear. In those cases when a reply is not received or when altitude data cannot be decoded, the system will coast and will update the trackers on previous data. Active BCAS can generate an avoidance maneuver advisory on a CAS track that is in a coast status. When six consecutive coasts occur, tracks will be dropped and the initiation cycle must be implemented to reestablish tracks.

The present data evaluation consisted of observing the BEU produced type 10 message records (CAS tracks, see appendix B, figure B-3) and counting the numbers of coasts which occur during the tracking cycle. This initial evaluation is limited to total target tracking performance in specific flight locations and selected planned encounters.

Table 24 represents the percentage coasts recorded on the Western and Eastern operational tour flights and planned encounter flights. The percentage coast is the ratio of the number of coasts to the total number of type 10 records. The number of records represents the total number of seconds of recorded data; the number of coasts represents the total number of coasts occurring in these total records. A coast is established by observing the number 10 record update time and the time of the latest report. If these times agree, the system is not in coast; but if they disagree, the system is in coast for that specific second. The data in table 24, in its present form, is a gross indication of coast performance in that it includes those coasts which resulted in a total track drop (not reestablished), and also those coasts for which the tracks were dropped for exceeding the system established range cutoff. This cutoff is presently set at approximately 14 nmi. In addition, it includes all existing track segments without respect to their length, what aircraft were producing the tracks, or where the aircraft were located. In addition, the data in the various cities could include both terminal and en route flight data. For these reasons, the data represent gross percentages and, therefore, comparisons should recognize present data limitations. Relative comparisons of the total coast percentages in table 24 indicate that the percentage coasts in California cities and, on occasions, New York, exceed the other locations by significant amounts. The average coast percentage of all California cities is 44 and New York, on its high days, is 40. The closest percentage to these two is 33 which occurred in Miami and Chicago.

Table 25 represents presently available 60-second maximum average density and fruit data from various cities on the given date. Comparison of tables 24 and 25 indicate that coast rates and fruit levels are correlated.

In order to gain additional insight into the overall coast percentage effect on track drops, planned encounter data from Los Angeles, Washington, D.C., and New Jersey were evaluated to establish the consecutive coast percentages with respect to the number (N) of coast occurrences (see table 26).

As an example, if we observe the Los Angeles July 19 data from table 26, we would find that there were a total of

TABLE 24. TOTAL TARGET COAST PERCENTAGE

Flight Location	Date (1980)	Total Coast Percentage		
		Records[1]	Number of[2] Coasts	Percentage
Los Angeles	7/18	40,393	19,166	47
Los Angeles	7/19	34,791	16,388	47
Los Angeles (N-40)	7/20	31,639	14,321	45
Los Angeles (N-49)	7/20	31,293	13,485	43
Dallas	7/14	24,448	5,880	24
Houston	7/14	25,364	7,540	30
Salt Lake City	7/16	34,134	10,204	30
San Diego	7/17	24,001	10,536	44
San Francisco/Oakland	7/24	14,024	5,506	39
Kansas City	7/25	14,163	3,704	26
Chicago	7/26	23,992	7,984	33
Atlantic City	8/26	15,317	3,276	21
Atlantic City	8/26	6,513	1,933	30
Atlantic City	9/26	6,789	2,039	30
Atlantic City	9/26	44,549	14,241	32
Atlantic City	10/8	9,428	2,246	24
Atlantic City	10/9	10,209	2,246	22
Miami	9/3	35,853	11,827	33
Washington, D.C.	6/28	16,158	4,628	29
Washington, D.C.	9/8	49,993	15,329	31
New York	9/25	33,744	9,543	28
New York	10/14	26,545	6,784	26
New York	8/28	68,572	29,129	42
New York	8/29	27,483	10,623	39

(1)Includes all targets. Both threats and nonthreats.
(2)Includes five coasts for each time a target leaves BCAS coverage.

TABLE 25. RELATIVE FRUIT AND DENSITY[1]

Flight Location	Date (1980)	Density[2]		Fruit[3]	
		Max.	Min.	Max.	Min.
Los Angeles	7/20[4]	10	0	29,000	4,000
Los Angeles	7/19	9	1	24,000	7,000
New York	8/29	12	1	18,000	3,000
Washington, D.C.	9/8	9	0	10,000	2,000
Atlantic City	9/26	9	0	2,000	1,000

(1)These represent the maximum and minimum 60-second averages recorded during the total flight time.
(2)60-second average of the number of CAS tracks within a 10-mile radius of the BCAS aircraft.
(3)±30-second average, about the acquisition time, for fruit rate estimate as described on page 7.
(4)Data from N-49.

TABLE 26. ENCOUNTER CONSECUTIVE COASTS

Flight Location	Date(1) (1980)	Number of Encounters Considered	Total Coast (%) Records	Coast(3)	Total %	N(4)	Percentage of Consecutive Coasts (Total) 1	2	3	4	5	6	Aircraft
Los Angeles	7/19 AD	11	980	363	37	209	56	18	11	3	1	11	N-40 - N-49
Los Angeles	7/20 A	11	735	411	56	169	40	25	10	14	1	10	N-40 - N-49
Los Angeles	7/20 A	12	340	207	61	78	39	19	15	12	1	14	N-49 - N-4[illegible]
Washington, D.C.	6/28 A	5	791	236	30	144	64	19	10	4	1	2	N-49 - N-4[illegible]
Washington, D.C.	6/28 AD	2	224	83	37	28	60	18	11	0	7	4	N-49 - N-4[illegible]
Washington, D.C.	6/28 D	2	259	9	3	3	67	0	0	0	0	33	N-49 - N-4[illegible]
Washington, D.C.	9/8 A	3	1,022	122	12	34	68	20	0	0	0	12	N-40 - N-5[illegible]
New Jersey	8/26 A	3	769	190	25	113	73	12	5	4	3	3	N-49 - N-4[illegible]
New Jersey	8/26 AD	4	885	316	36	156	59	20	12	3	4	2	N-40 - N-49
New Jersey	8/26 D	4	812	21	3	9	67	11	11	0	0	11	N-40 - N-49
New Jersey	9/26 A	20	2,649	1,356	51	649	49	23	12	6	4	6	N-40 - N-49
New Jersey	9/26 A	20	4,379	1,101	25	627	67	20	7	3	1	2	N-40 - N-4[illegible]
New Jersey	9/26 A	4(2)	592	163	28	94	73	15	5	1	1	5	N-49 - N-40
New Jersey	9/26 A	4(2)	411	198	48	116	55	24	9	6	2	4	N-40 - N-49

(1) D = DABS only replies, A = ATCRBS replies from aircraft ATCRBS transponder, AD = ATCRBS replies from DABS transponder.

(2) These four runs are those in which both BEUs' were operating.

(3) Includes coasts from initial acquisition through crossover and during outbout leg. It does not include any coasts beyond the coverage area (approximately 14 nmi).

(4) N = Number of coast occurrences.

363 individual seconds of coast. These individual coasts could be observed in the message type 10 (appendix B, figure B-3) to be occurring in groups of one through five. On the next second, or sixth consecutive coast, the target track will be dropped. These groupings are indicated in table 26 under the heading of "Percentage of Consecutive Coasts." In table 26, the number N that is associated with the July 19 Los Angeles data is 209 and represents the total number of track coast occurrences. Each one of these 209 occurrences could contain anywhere from one to six consecutive coasts. The percentage of consecutive coasts in table 26 is achieved by calculating the ratio of the number of coast events in each category (1,2...6) to the total of N events. A general observation of the table 25 data is that the highest percentage of coasts are single occurrences and the percentages decrease with increasing numbers of coasts, except for the track drop number six. Therefore, despite high levels of total coast percentages (e.g., 47 percent in Los Angeles, figure 22), the chances of dropping tracks is much lower, as indicated by the percentage occurrence of six consecutive coasts.

The probability of dropping track when in coast, based on the observed percentages in table 26, for ATCRBS operation is a worst case for the N-49 and N-40 combination at Los Angeles on July 20 and is approximately 8.5 percent (0.61 x 0.14) and is a best case for the N-49 and N-47 combination at Wash ngton, D.C., on June 28 and is approximately 0.6 percent (0.30 x 0.02).

The data in table 26 under category 6 generally does not include the six consecutive coasts that occurred as a result of dropping track due to the 14-nmi system track limit. It does, however, include track coasting from initial acquisition through the outward leg track drop.

The following general observations can be made from tables 24 and 26.

1. DABS track coast percentages are small compared to ATCRBS or ATCRBS DABS (table 26).

2. Track drop percentages were occurring at consistently higher rates in California than in other areas of consideration (table 24). This indicates a higher probability of dropping track in more dense environments.

3. The number of seconds of data (records) for total number of encounters is lower in California (table 26). Some of this reduction is due to data gaps caused by buffer sizes and data recording transfer rates; however, this reduced track record size is correlated with the higher track drop percentages.

Table 27 represents statistical tests to determine if track coasting performance of N-40 versus various target aircraft was consistent, and if the N-40 and N-49 BEU performance was consistent. Had the performance been consistent, the data from various days could have been combined and a single probability estimate based on observed percentages for dropping tracks could have been made. As can be observed from the comparisons, the N-40 and N-49 combinations are all different with respect to different aircraft combinations. Where a direct comparison could be made between the N-40 BEU versus N-49 BEU on the same data, the results are inconclusive. The July 20 two aircraft comparisons are not significant, but the September 27 are. Based on these preliminary evaluations and observation of tables 24 through 26, indications are that higher fruit and track density areas cause greater track discontinuities and greater coast percentages.

The data in table 28 indicate that the performance of the ATCRBS mode of DABS

TABLE 27. TOTAL COAST PERCENTAGE STATISTICAL COMPARISONS ATCRBS

Comparisons[1]	Total Coast[4] Percentage	CHI Sq. 0.05[2] Calculated	Statistical[3] Results
N-40 - N-49 (7/19) versus N-40 - N-49 (7/20)	37 (980 - 363) 56 (735 - 411)	63.1	S
N-40 - N-49 (7/20) versus N-40 - N-49 (9/26)	56 (2649 - 1356) 51 (735 - 411)	5.1	S
N-40 - N-49 (7/19) versus N-40 - N-49 (9/26)	37 (980 - 363) 51 (2649 - 1356)	56.5	S
N-40 - N-49 (7/19) versus N-40 - N-5 (9/8	37 (980 363) 12 (1022 122)	170.0	S
N-40 - N-49 (7/14) versus N-40 - N-47 (9/26)	37 (980 363) 25 (4379 - 1101)	56.5	S
N-40 - N-49 (7/20) versus N-49 - N-40 (7/20)	56 (735 411) 61 (340 207)	2.1	NS
N-40 - N-49 (9/26) versus N-49 - N-40 (9/26)	48 (411 198) 28 (592 163)	44.0	S

(1) Represents aircraft combinations whose performances were compared.

(2) CHI square test of percentages at 0.05 level of significance. If calculated value is greater than 3.84, the percentages are significantly different from each other.

(3) S = Significantly different, NS = not significantly different.

(4) Bracketed values represent total records and coasts.

TABLE 28. TOTAL COAST AND TRACK DROP STATISTICAL COMPARISONS

Comparisons[1]	Data Type[2]	Total Coast %	x2 Cal.[3] 0.05	Track Drop %	x2 Cal.[3] 0.05
N-40 - N-49 (7/19)	ATCRBS-DABS	37		11	
versus			0.005		0.79
N-49 - N-47 (6/28)		37		4	
N-40 - N-49 (7/19)	ATCRBS-DABS	37		11	
versus			0.302		9.80
N-40 - N-49 (8/26)		36		2	
N-49 - N-47 (6/28)	DABS	3		33	
versus			0.280		0.00
N-40 - N-49 (8/26)		3		11	

(1)Represents aircraft combinations whose performances were compared.

(2)ATCRBS - DABS = ATCRBS replies from DABS transponder.
DABS = DABS replies from DABS transponder.

(3)This calculated value when greater than 3.84 indicates that the compared data are significantly different. These tests are insensitive to small samples.

transponder replies, relative to total coast probability (percentage), is not different in any of the locations; however, the probability of dropping track when in coast is worse in Los Angeles than in New Jersey (11 percent versus 2 percent).

Based on the total coast and track drop percentages in table 28, it can be estimated that the joint probability of being in coast and then dropping track in the ATCRBS/DABS mode was a worst case, 4.1 percent (0.37 x 0.11) in Los Angeles on July 19 and a best case, 0.7 percent (0.36 x 0.02) in Atlantic City on August 26.

The performance of DABS tracks relative to coast probability and the probability of dropping track when in coast is not significantly different in Washington and New Jersey (see table 28). Although 33 percent versus 11 percent would indicate a difference, the comparisons being made are one coast out in three occurrences and one coast out in nine occurrences. The statistical tests are insensitive to these small sample sizes and, therefore, indicate no difference. Based on the DABS data in table 28, the joint probabilities of being in coast and then dropping track is 1 percent in Washington (June 28) and 0.3 percent in Atlantic City (August 26).

TARGETS OF OPPORTUNITY.

During CAS test flights, detailed logs were kept by BCAS project personnel that recorded information which could be used in subsequent flight analysis. This information included all advisories as well as close proximity aircraft

sightings for which no advisories were generated. When advisories or sightings occurred which were not part of planned encounters, the aircraft involved were called "targets of opportunity" or "random targets."

Twenty-three targets of opportunity from 13 geographical locations were examined. Table 29 lists the encounters which occurred after the July 13 version 6 software freeze and also shows advisories, advisory times, range separation, altitudes, etc. Six random targets were encountered on piggyback flights. Two of these occurred when CAS track messages were not being recorded by the BEU. In these cases, the logs were relied upon to examine the situation.

Other advisories were examined but are not included because they were caused by other aircraft near or on the ground.

For all of the targets of opportunity, except the two where track data were not recorded, plots are included showing the altitude of the BCAS aircraft and other aircraft, the range separation, and the advisories. A solid vertical line represents the start of an advisory; a dashed vertical line represents the termination of an advisory. When no advisory was generated, a solid line is shown through the point of closest approach. The advisories are designated by letters in the following manner:

C = Climb
D = Descend
NC = Don't climb
ND = Don't descend
LC = Limit climb
LD = Limit descend

Each target of opportunity which produced an advisory was examined to see if it was caused by another aircraft, which aircraft it was, and if the advisory had the correct sense. For example, if both aircraft were flying level with BCAS below and the advisory was either "don't climb," "limit climb," or "descend," it would have the correct sense. For those targets of opportunity where no advisories were produced, the position of the aircraft relative to BCAS was examined to see if an alarm should have been generated.

Dallas Texas, July 14, 1980.

This random encounter occurred near Dallas, Texas, on July 14, 1980. Plots are shown in figures 39 and 40. Altitude tracks of the target and BCAS aircraft show they were flying a near parallel course. When the range separation decreased to 1.12 nmi, advisories were generated. Although the only advisory displayed was don't climb, an examination of the CAS track file messages showed that some of the time descend advisories were selected. The logic which causes this change of advisory is driven by a trip signal from the ship's radar altimeter. When the BCAS aircraft is at 900 feet or below, this signal changes the descend advisory to a don't climb advisory. On this flight, the trip signal was such that it was always indicating we were below 900 feet causing the advisory change. No other system function was affected by this problem. The CAS logic advisories are shown on the plot in figure 44. The advisory sequence was descend, don't climb, no advisory, don't climb, descend. During this time, range separation decreased from 1.12 to 0.38 nmi and altitude separation from 300 to 413 to 293 feet. When the relative altitude rate was positive, the aircraft were separating and the don't climb and no advisory were generated. When the relative altitude rate was negative, they were closing and the descend advisory was generated.

The final descend advisory was dropped, although the range and altitude separation was decreasing. A further review of data showed that performance level was changed from a value of four to three. The second that occurred the

TABLE 29. TARGETS OF OPPORTUNITY

Date (1980)	Location	Advisory Time	P.L.	Advisories	Range TAU (sec)	Range (nmi)	Alt. BCAS (ft)	Alt. Other (ft)
7/14	Dallas, Texas	4968-4996	4 & 3	D,NC,D	21.3	1.14	1,800	618
7/14	Houston, Texas	2787-2804	4	C,ND	22.3	1.81	1,481	1,712
7/15	Denver, Colorado	2174-2195	4	C,ND,C	18.7	2.26	10,693	9,981
7/15	Denver, Colorado	4049-4050	3	NC	16.0	1.14	5,793	6,368
7/16	Salt Lake City, Utah	4602-4621	3	ND,C,ND	18.8	2.06	5,268	5,156
7/18	Los Angeles, California	6078-6079	4	LD	24.0	2.15	7,700	7,150
7/19	Los Angeles, California	2785-2795	4	C,ND	22.9	2.02	7,793	7,631
7/19	Los Angeles, California	6636-6673	4	D	22.4	1.75	2,393	1,762
7/20	Los Angeles, California	1447-1453	4	1000 LD	23.7	2.28	1,100	837
7/23	Seattle, Washington	3491-3499	4	ND,1000 LD				
7/24	San Francisco, California	3026-3033	4	NC				
7/24	San Francisco, California	7199-7207	4	ND,C	23.1	1.12	2,893	3,193
7/24	San Francisco, California	7214-7219	4	NC	23.7	3.2	5,000	4,893
8/4	Canton, Ohio	1381-1404	5	NC	26.2	5.67	16,000	15,550
8/8	Canton, Ohio	848-863	5	D,NC	28.2	3.12	10,000	11,300
10/8	FAA Technical Center	6416-6445	4	NC,LC,NC	27.32	1.90	4,700	5,112

NOTES: P.L. is BEU performance level.
Range, Range TAU, BCAS Alt., and Other Alt. values are for start of advisory time.

the advisory was dropped. The range TAU went from a value of about 6 seconds to a value of 25.6 seconds, which is high enough to prevent advisories.

The sense of the advisories appear to be correct for the circumstances of the encounter.

Houston, Texas, July 14, 1980.

At Houston, Texas, on July 14, 1980, a small aircraft was encountered. Plots of this encounter are shown in figures 41 and 42. At the start of the track, the BCAS aircraft was below. At 2,772 seconds they were coaltitude, but the range separation was about 5 nmi. They continued to close in range while crossing altitudes until the range was 3.21 nmi and the altitude separation was 107 feet with BCAS above. At this point, a climb advisory was generated. At 2.5-nmi range separation, 213 feet altitude separation, and BCAS climbing the advisory was reduced to don't descend. This advisory was displayed for 12 seconds, then dropped when the range difference was 1.21 nmi and the altitude difference 562 feet. The advisories for this encounter were correct.

Denver, Colorado, July 15, 1980.

This target of opportunity occurred at Denver, Colorado, July 15, 1980. Plots of the encounter are shown in figures 43 and 44. The BCAS aircraft was above and flying almost level, while the other aircraft was gradually climbing and eventually passes through the BCAS altitude. At 2,174 seconds, a climb, don't descend, climb series of advisories was started. The range and altitude differences were 2.26 nmi and 712 feet, respectively. At the start of the don't descend advisory, BCAS was starting to climb and the altitude rate was positive. Both aircraft were then climbing, but the intruder at a faster rate, and when the altitude separation decreased to 519 feet, the climb advisory was again displayed. At a range separation of 0.87 nmi and altitude separation of 507 feet, the range rate went positive and the climb advisory was dropped. These advisories had the correct sense.

Denver, Colorado, July 15, 1980.

A don't climb advisory was generated on a random target at Denver, Colorado, on July 15, 1980. Plots of this encounter are shown in figures 45 and 46. Both aircraft were descending with BCAS below. The advisory appears to be correct; however, the CAS track was in coast when it was issued and was using data 3 seconds old. The track then coasted out and no new track was found in the data. From the data available, BCAS was below and the don't climb advisory is the proper sense.

Salt Lake City, Utah, July 16, 1980.

This target of opportunity occurred at Salt Lake City, Utah, on July 16, 1980. Plots of this encounter are shown in figures 47 and 48. The BCAS aircraft was below and climbed through the altitude of intruder aircraft. When they were coaltitude, the range separation was about 2.58 nmi. Five seconds later, at a range separation of about 2 nmi and altitude separation of 112 feet above BCAS, a don't descend advisory was displayed. When the range difference decreased to 1.5 nmi and altitude difference was 162 feet, the advisory changed to climb. When the range and altitude differences were 1 nmi and 588 feet, the advisory changed back to don't descend.

At the closest point of approach, the range separation was 0.37 nmi and altitude separation was 579 feet. The advisories appear to have had the correct sense for these conditions.

Los Angeles, California, July 18, 1980.

This random encounter occurred near Los Angeles, California, after a series of planned encounters was completed. Some data are missing before, during, and after the advisory, but enough data are present to examine the encounter. Plots of the encounter are shown in figures 49 and 50.

Prior to and during the advisories, BCAS was flying level at 7,700 feet. The other aircraft was descending from 7,300 feet (range 3.5 nmi) and when the advisory was dropped, its position was 7,050 feet (range 1.44 nmi).

When the first advisory limit descend 1,000 was generated, the altitude separation was 550 feet, the range separation was 2.15 nmi, and the relative altitude rate was 780 fpm separating. The advisory changed to limit descend 2,000, and then the advisory was dropped. Two seconds of data are missing after the last advisory is shown in the data.

The advisories and their sense were correct as the other aircraft was below and they continued to separate in altitude.

Los Angeles, California, July 19, 1980.

Another target of opportunity was encountered at Los Angeles, California, on July 19, 1980, and resulted in advisories of climb and don't descend. The plots are shown in figures 51 and 52. At the time of the climb advisory BCAS was above the target, the vertical separation was 162 feet, and the range about 2 nmi. When the don't descend advisory was displayed, the target was descending while the BCAS was flying level. The point of closest approach occurred after the advisories when the range separation was 0.16 nmi and the altitude separation was 813 feet. The advisories and their sense were correct for this situation.

Los Angeles, California, July 19, 1980.

This encounter at Los Angeles, California, on July 19, 1980, involved the BCAS aircraft, a planned encounter aircraft, and an intruder aircraft. All three aircraft were flying approximately level, BCAS at 8,200 feet and the other two aircraft at 8,500 feet. The plots for this encounter are shown in figures 53 and 54.

A descend advisory was generated by the CAS logic, although don't climb was displayed. This was due to a problem with the radar altimeter signal, which was previously described. Aircraft No. 1 generated the advisory for the first 8 seconds. Then both aircraft generated descend advisories for the next 18 seconds.

At the start of the advisory, aircraft No. 1 was 300 feet above BCAS, the range was 2.12 nmi, and the range TAU was 22.4 seconds. When aircraft No. 2 started contributing to the advisory, its range was 3.5 nmi and the range TAU was 22.9 seconds. Aircraft No. 2 dropped the advisory 3 seconds before aircraft No. 1, when it coasted out near zero range. When it coasted out, the range jumped to a value 63.93 nmi. This is a known system problem that is being corrected. When aircraft No. 2 track dropped the advisory, its range rate was positive and the aircraft were separating. The advisories produced by each aircraft appear to have the correct sense.

When aircraft No. 1's range dropped below 0.25 nmi, the range jumped to 0.47, 0.48 nmi, and then to 0.23 nmi. The range rate went from -216 to +179, to +128, and then to -214 feet per second. These two inconsistent range values can be seen on figure 54 between the time 6660 and 6670. It appears that the reports used in updating the track were not consistent with the track.

Los Angeles, California, July 20, 1980.

Another target of opportunity occurred at Los Angeles, California, July 20, 1980, and a limit descend 1,000 advisory was generated. The plots for this encounter are shown in figures 55 and 56. BCAS was flying level at 8,200 feet; the other aircraft was climbing from 4,900 feet and would eventually pass through the BCAS altitude. A maximum altitude rate of 2,940 fpm was recorded at 1,452 seconds during advisory time and 3 seconds prior to the range rate going positive. The limit descend advisory was displayed when the range TAU was equal to 8.9 seconds, the altitude separation 1,094 feet, and the vertical TAU 24.9 seconds. An altitude separation of 832 feet was realized at the point of closest approach, 0.81 nmi. When both planes were coaltitude, they were separated in range by about 3.30 nmi. From these data, it appears that the sense of the advisory was correct.

Seattle, Washington, July 23, 1980.

On July 7, 1980, at Seattle, Washington, don't descend and limit descend 1,000 advisories were generated. Plots are shown in figures 57 and 58. BCAS was flying approximately level, while the other aircraft was below and gradually descending. Initially, the range separation was 2.34 nmi and altitude separation 575 feet. When the advisories were dropped, the range separation was 1.47 nmi and altitude separation 744 feet. The sense of the advisories was correct.

San Francisco, California, July 24, 1980.

In San Francisco, California, on July 24, 1980, two aircraft were in close proximity, one produced a don't climb advisory while the other did not produce an advisory. Plots of the altitudes of BCAS and the two intruders and the range to both intruders are shown in figures 59 and 60. There are data missing for about 158 seconds prior to the advisory; however, sufficient data are available to examine the situation from this point on. BCAS performance was set to level 4 for tests purposes during this encounter. Normal performance for the altitude of this encounter is level 2, which precludes display of advisories.

When the don't climb advisory was generated for aircraft No. 1, the altitude separation was 607 feet, the range difference was 0.78 nmi, and the range TAU was 10.4 seconds. The advisory was dropped at the point of closest approach when the altitude difference had increased to about 670 feet and the range was 0.67 nmi. From the plot it can be seen that the range separation then continues to increase to about 2 nmi. The advisory and its sense were appropriate for this encounter.

Aircraft No. 2 came within 0.38 nmi in range, but the altitude separation was 1,913 feet. This is shown on the plots by the vertical line. The smallest altitude difference was 1,700 feet. The range separation at this time was 1.57 nmi. No advisory was generated on this aircraft, which is correct.

San Francisco, California, July 24, 1980.

On July 24, 1980, at San Francisco, California, two targets of opportunity produced advisories during a short period of time. Plots are shown in figures 61 and 62. BCAS is descending and aircraft No. 1 appears to have taken off and is climbing. Three seconds of data are missing prior to the start of the don't descend advisory so the data which initiated the advisory cannot be examined. As they continued to close in range and altitude, the advisory went positive to climb. Data are missing when the advisory is dropped; however, looking at the first second of data after the advisory is dropped shows the vertical TAU being greater than the

25-second threshold. It appears that the sense of the advisories was correct.

A track was started on a second aircraft (aircraft No. 2 on the plots) during the last seconds of the advisory on aircraft No. 1. This plane was coaltitude with the BCAS and at a range of 2.3 nmi. When the 25-second range TAU was broken, a don't climb command was generated. They continued to separate in altitude at about 1,600 fpm and the advisory was dropped. Like the first two advisories, this advisory appears to have the correct sense.

The sequence of advisories displayed — don't descend, climb, and don't climb — appear to contain a sense change; however, it can be seen that the third advisory was actually caused by another aircraft.

In following the CAS track of aircraft No. 1 after the advisories, the data showed it closed in range to 0.01 nmi (61 feet) while the altitude separation was 769 feet. The range separation can never be less than the altitude separation. The tracker is in coast at this time and the update data are 3 seconds old. Selecting a time just prior to the coast shows a range separation of 922 feet and altitude separation of 787 feet — a difference of only 35 feet. No advisory was generated because the vertical TAU was greater than 25 seconds.

Canton, Ohio, August 4, 1980.

Near Canton, Ohio, on August 4, 1980, a DC-9 caused a don't climb advisory. Plots of this encounter are shown in figures 63 and 64. The BCAS aircraft was flying level at 16,000 feet and the BEU was operating in performance level 5. The other aircraft was below and climbing. A maximum altitude rate (as calculated by the BEU) of 3,240 fpm was recorded 5 seconds prior to the advisory. At the time the advisory was issued, the altitude rate had decreased to 1,800 fpm and the altitude separation had decreased to 450 feet. The range separation was now 5.67 nmi. The calculated true range TAU and vertical TAU are 31.8 seconds and 15 seconds, respectively, indicating that the other aircraft would pass through the BCAS altitude before the range would go to zero. Consequently, the other aircraft would be above the BCAS aircraft. The vertical miss distance using true TAU was 504 feet above BCAS. Therefore, the don't climb advisory had the correct sense when it was initially displayed.

The DC-9, however, did not follow the initial projected path and it leveled off below BCAS. The apex of the climb occurred at 15,550 feet during the first 2 seconds of the advisory time. The DC-9's altitude then began to gradually decrease. The BEU altitude rate tracker did not indicate this change for 11 seconds. Calculations at this time, using BEU data, show the other aircraft about 550 feet below BCAS. The advisory sense did not reflect the new position of the intruder, but the BEU logic inhibits the changing of the sense of a displayed advisory until an advisory sequence or track is terminated. The present BEU tracker can, on occasion, result in this type of occurrence.

The Analysis Branch at the Technical Center used the data from this encounter as an input to a dynamic tracker. The results indicate that this tracker would have reduced the incorrect sense choice period. This dynamic tracker and other trackers which are capable of reducing these occurrences are being considered for implementation in the BEU.

Canton, Ohio, August 8, 1980.

Near Canton, Ohio, on August 8, 1980, a random encounter produced commands of descend and don't climb. Plots are shown in figures 65 and 66. BCAS was flying level at 10,900 feet, while the other aircraft was about 400 feet above.

This condition existed from a range separation of about 13 to 3.3 nmi, at which time the range TAU was less than 30 seconds (performance level 5). These two conditions, of 400 feet altitude separation and range TAU of less than 30 seconds, produced a positive descend command. When the command changed to don't climb the intruder was starting to climb and the altitude separation was increasing. The don't climb command was dropped when the range TAU exceeded 30 seconds and the altitude separation was about 512 feet. The commands and their sense were correct.

FAA Technical Center, October 8, 1980.

This target of opportunity occurred near the FAA Technical Center on October 8, 1980, and generated advisories of don't climb, limit climb 1,000, and don't climb. Plots showing the advisories are shown in figures 67 and 68. Prior to the advisories, the two aircraft passed through the same altitude at a range of about 5 nmi. BCAS continued to gradually descend until just prior to advisory time when it started a gradual climb. The intruder aircraft continued at a slow rate of climb.

The range TAU of 25 seconds was broken when the range separation was 1.9 nmi, the altitude separation was 412 feet, and a don't climb command was generated. The aircraft continued to separate in altitude and a limit climb 1,000 advisory was displayed. The third advisory in the sequence is don't climb. The aircraft are vertically separating at a rate of 720 fpm and the altitude difference is 600 feet. These advisories appear to have the correct sense.

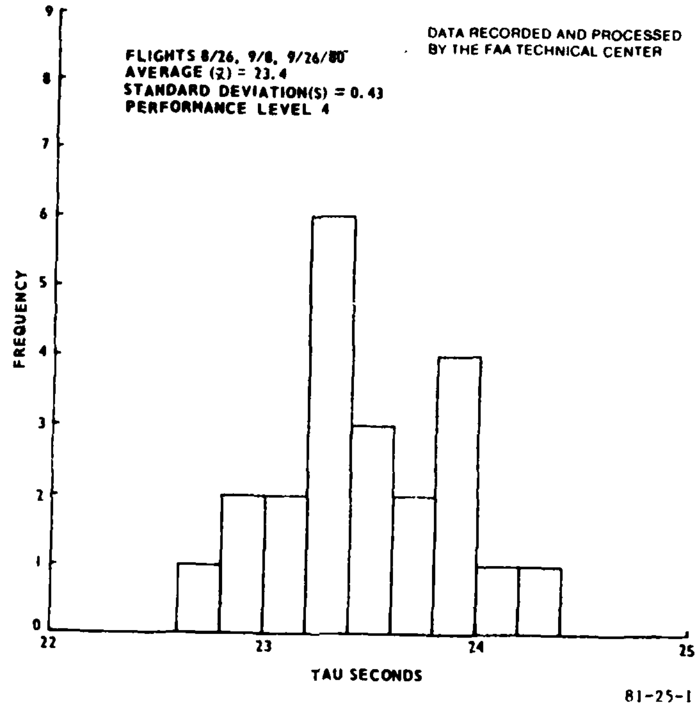


FIGURE 1. ATCRBS TAU HISTOGRAM

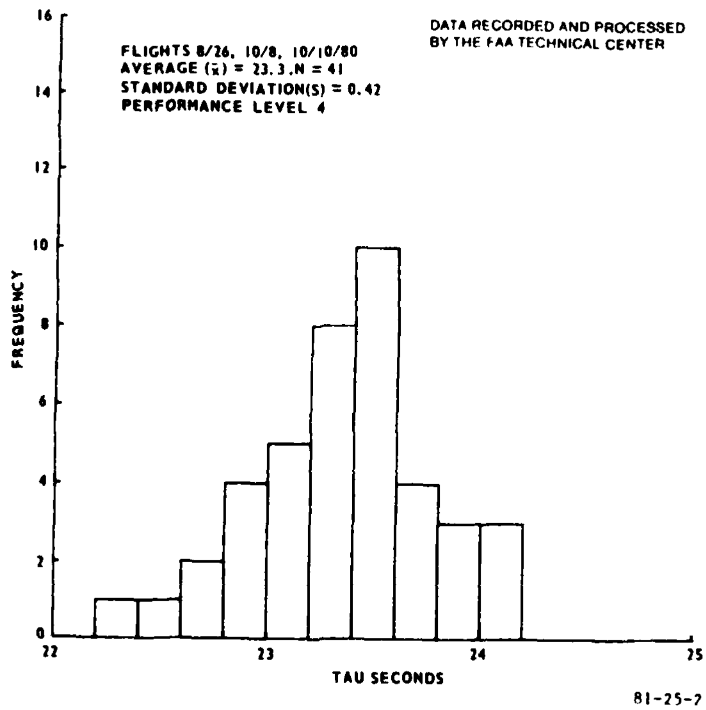


FIGURE 2. DABS TAU HISTOGRAM

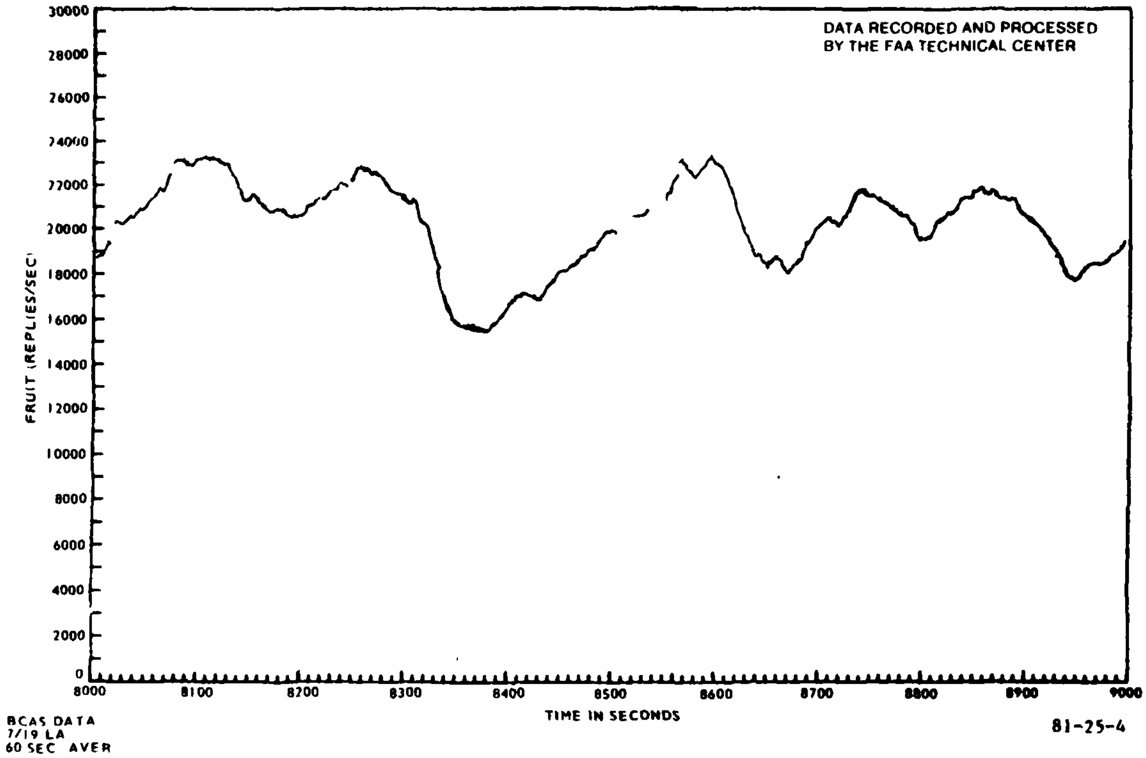


FIGURE 3. LOS ANGELES MAXIMUM AVERAGE DENSITY, JULY 19, 1980

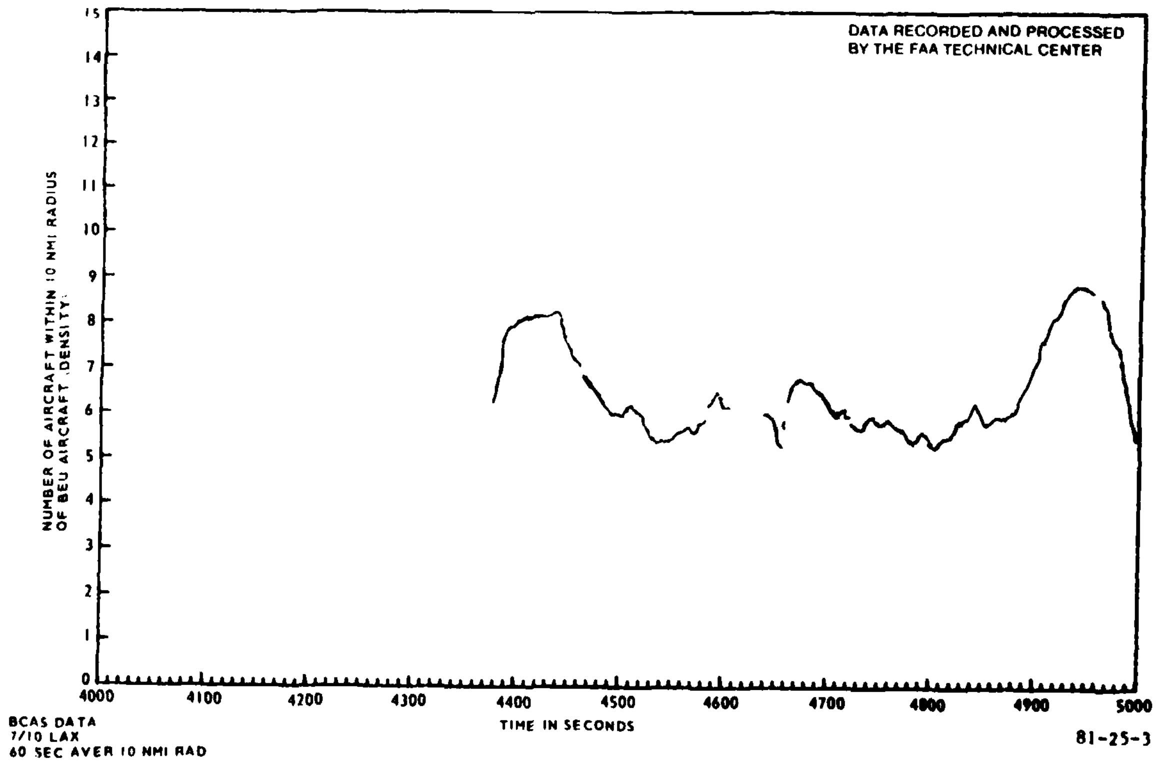


FIGURE 4. LOS ANGELES MAXIMUM AVERAGE FRUIT, JULY 19, 1980

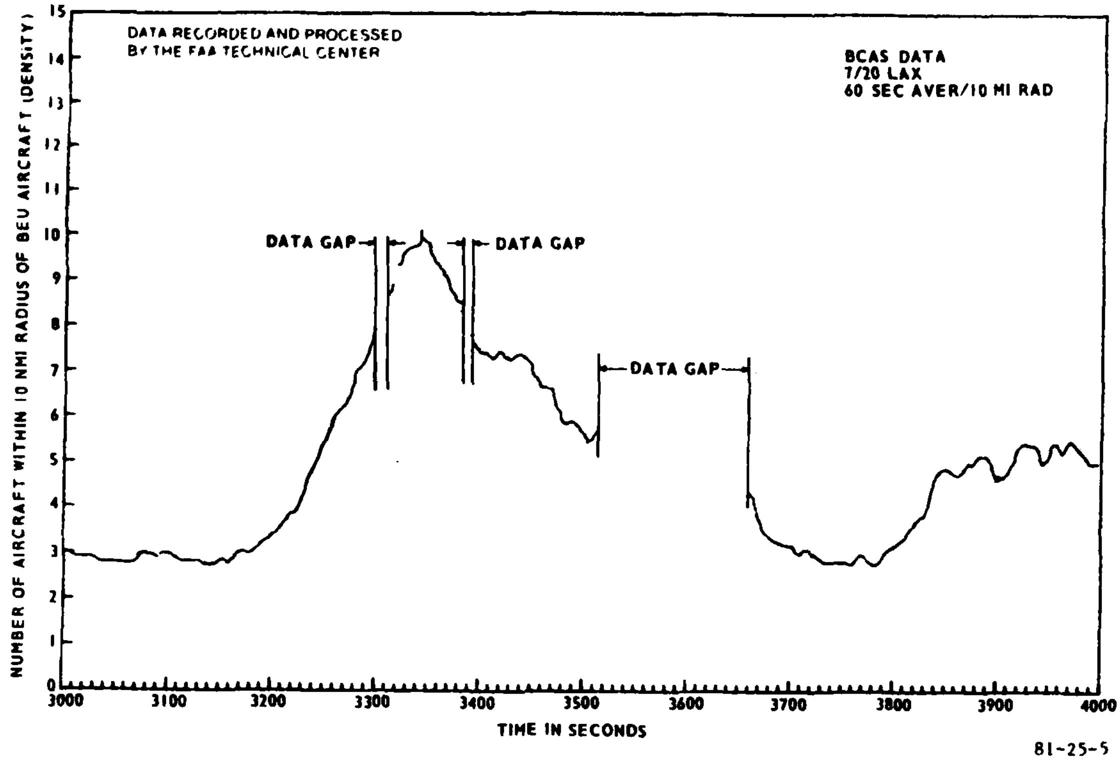


FIGURE 5. LOS ANGELES MAXIMUM AVERAGE DENSITY, JULY 20, 1980

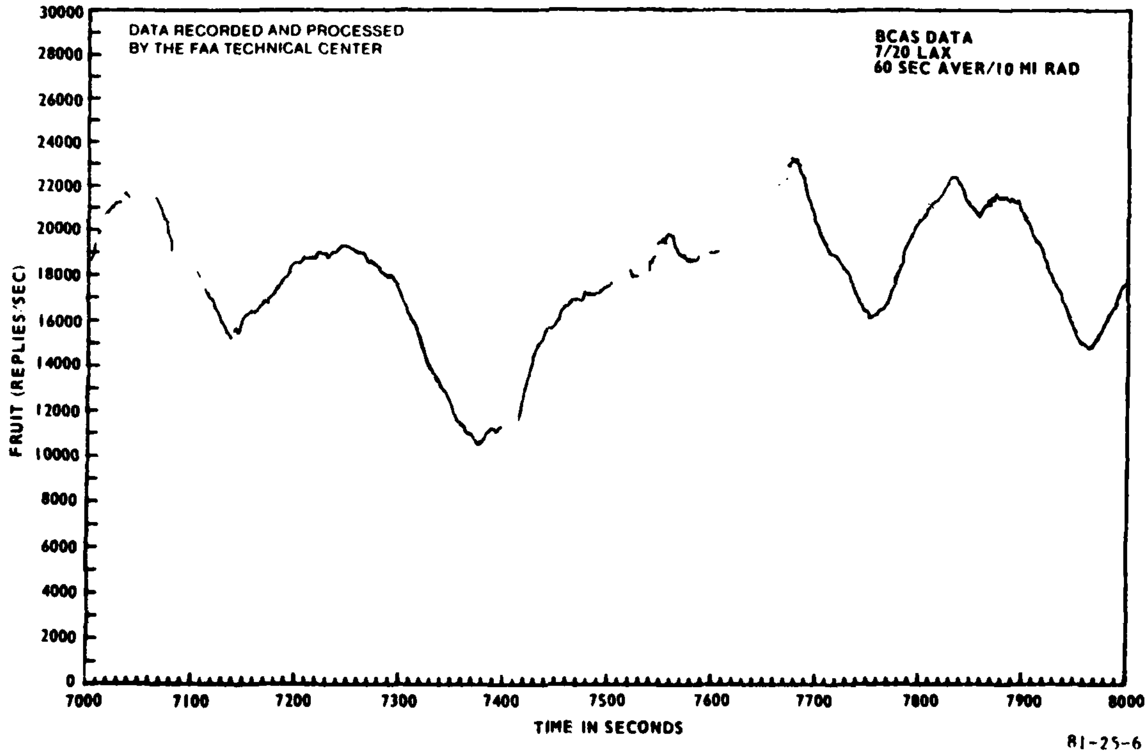


FIGURE 6. LOS ANGELES MAXIMUM AVERAGE FRUIT, JULY 20, 1980

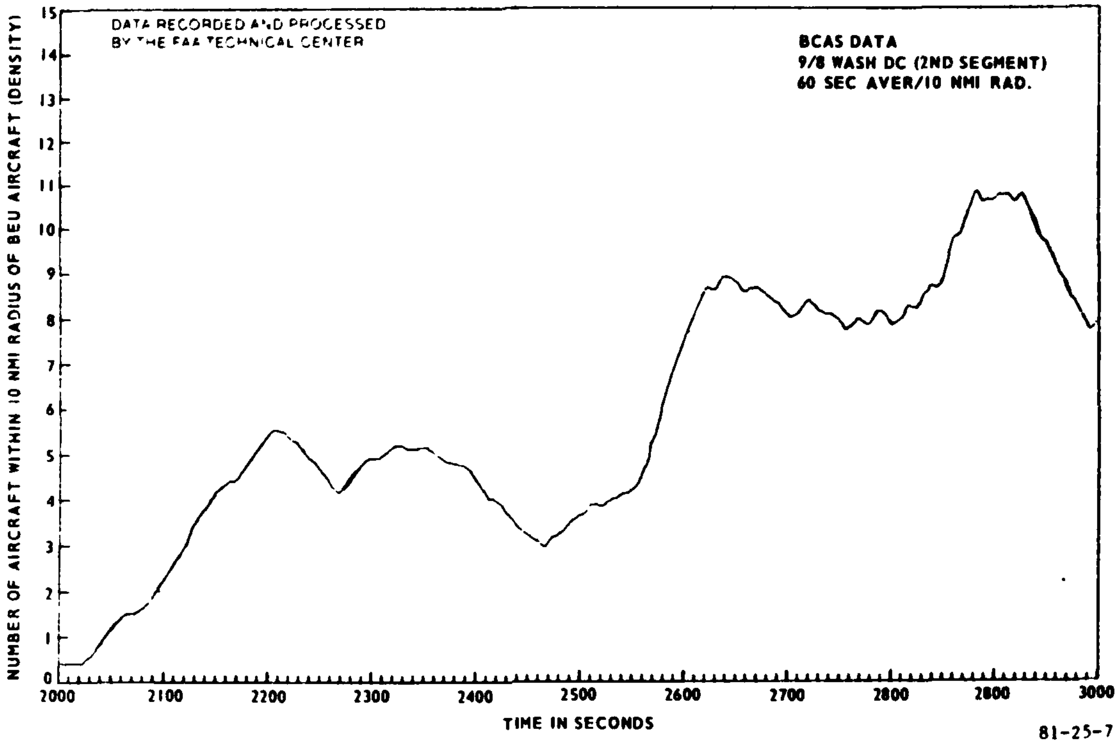


FIGURE 7. WASHINGTON, D.C., MAXIMUM AVERAGE DENSITY

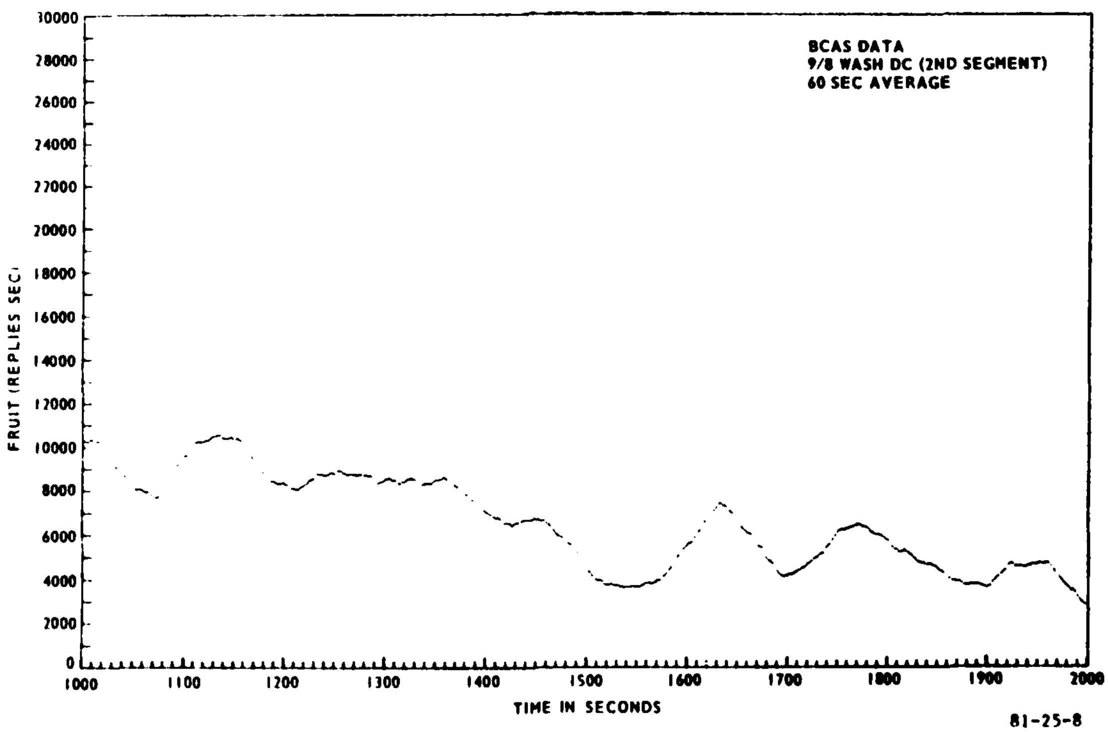


FIGURE 8. WASHINGTON, D.C., MAXIMUM AVERAGE FRUIT

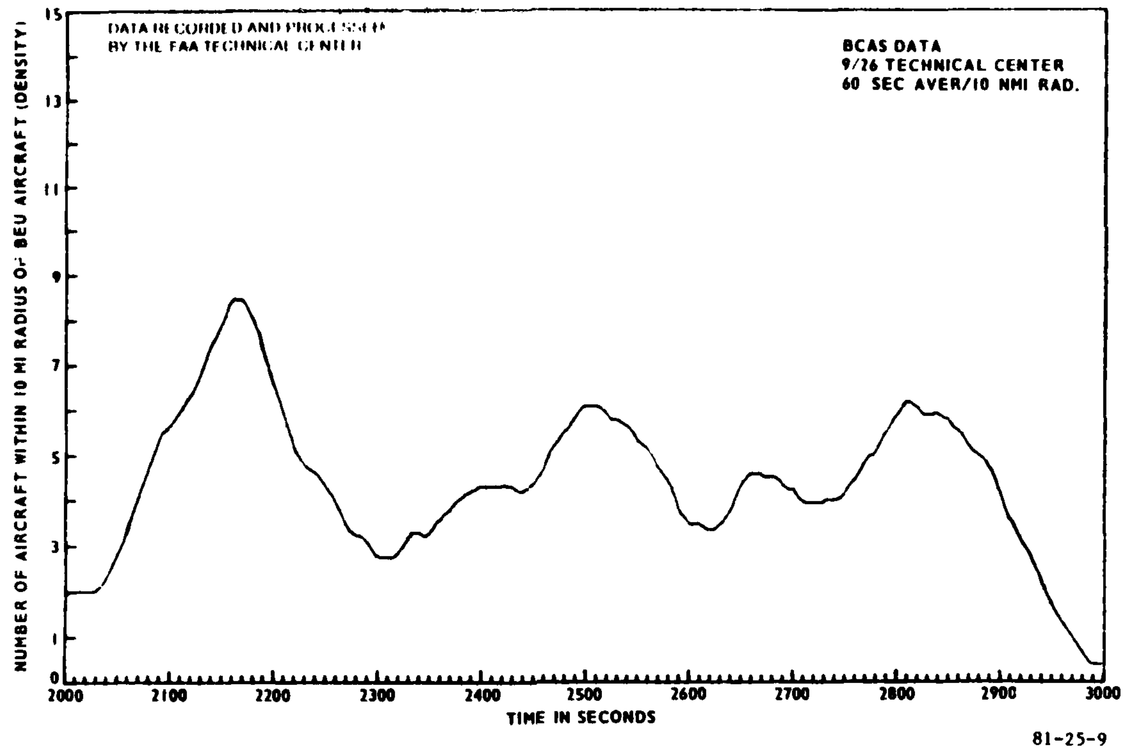


FIGURE 9. FAA TECHNICAL CENTER MAXIMUM AVERAGE DENSITY

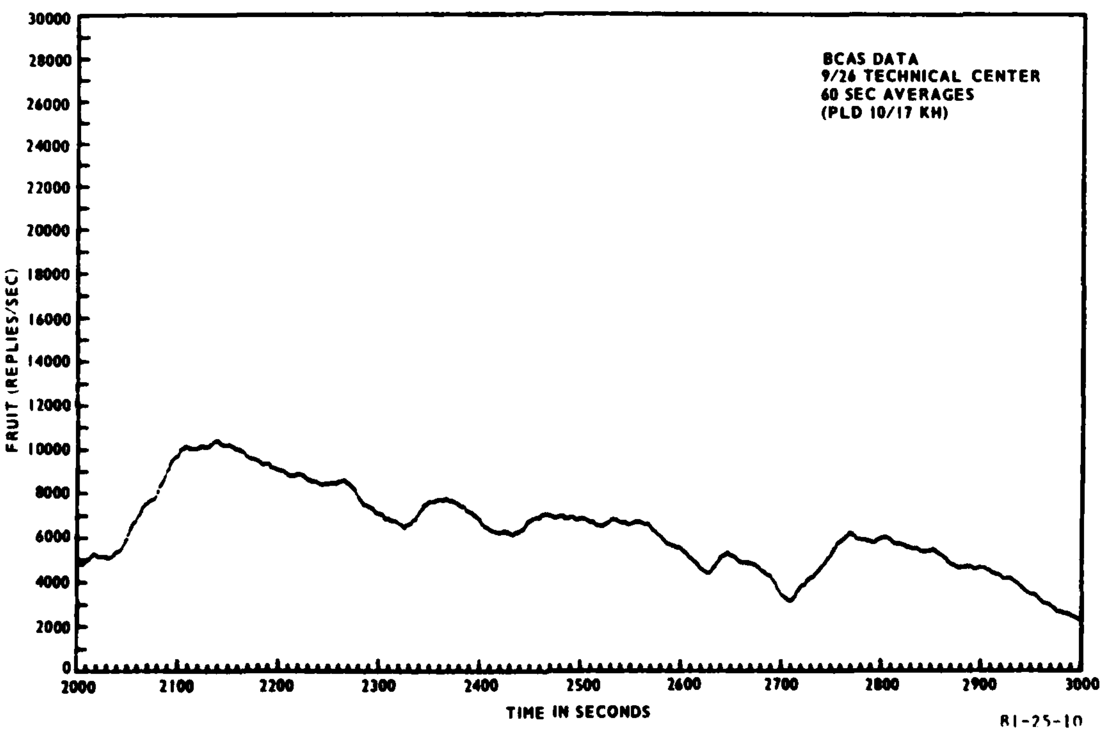


FIGURE 10. FAA TECHNICAL CENTER MAXIMUM AVERAGE FRUIT

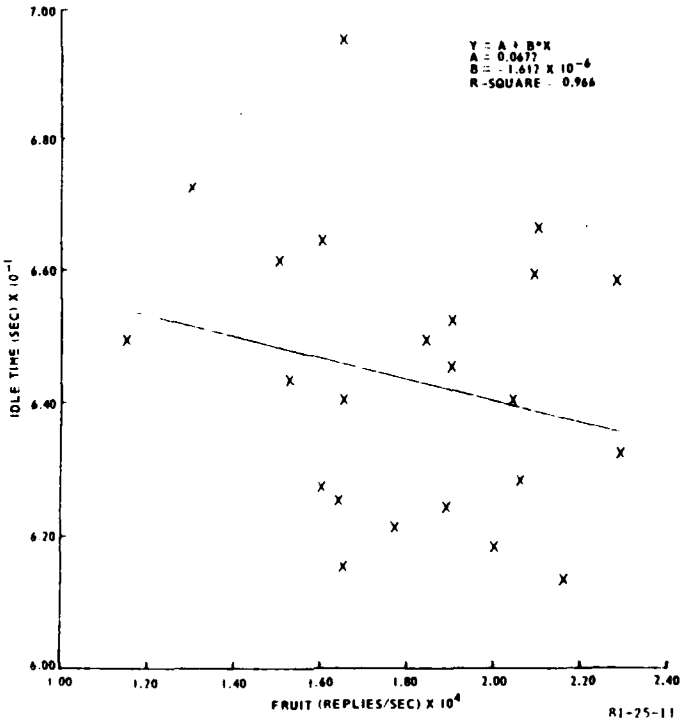


FIGURE 11. FRUIT VERSUS IDLE TIME, LOS ANGELES, JULY 19, 1980

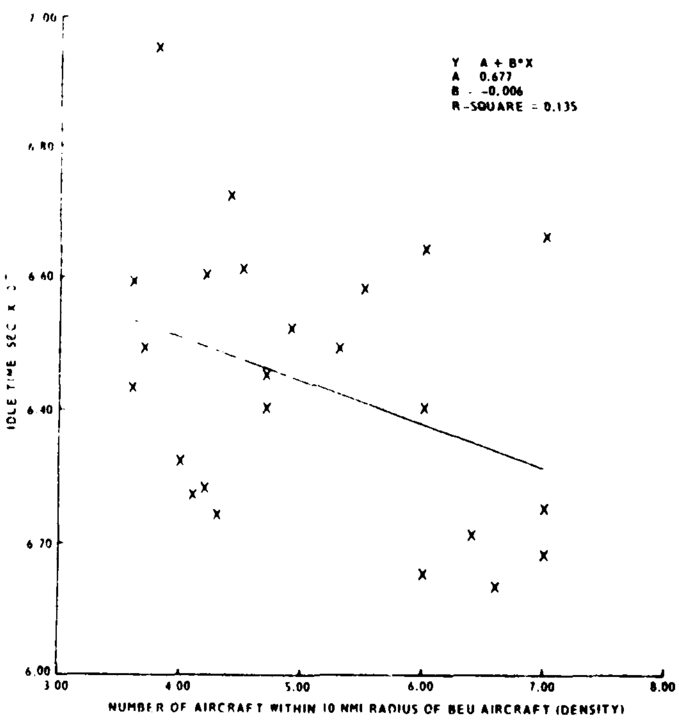


FIGURE 12. DENSITY VERSUS IDLE TIME, LOS ANGELES, JULY 19, 1980

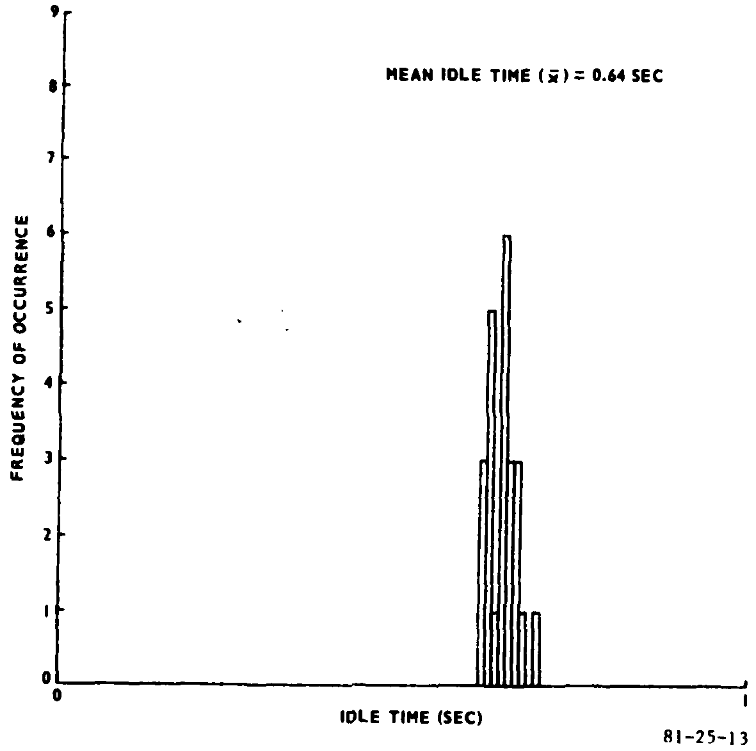


FIGURE 13. IDLE TIME HISTOGRAM, LOS ANGELES, JULY 19, 1980

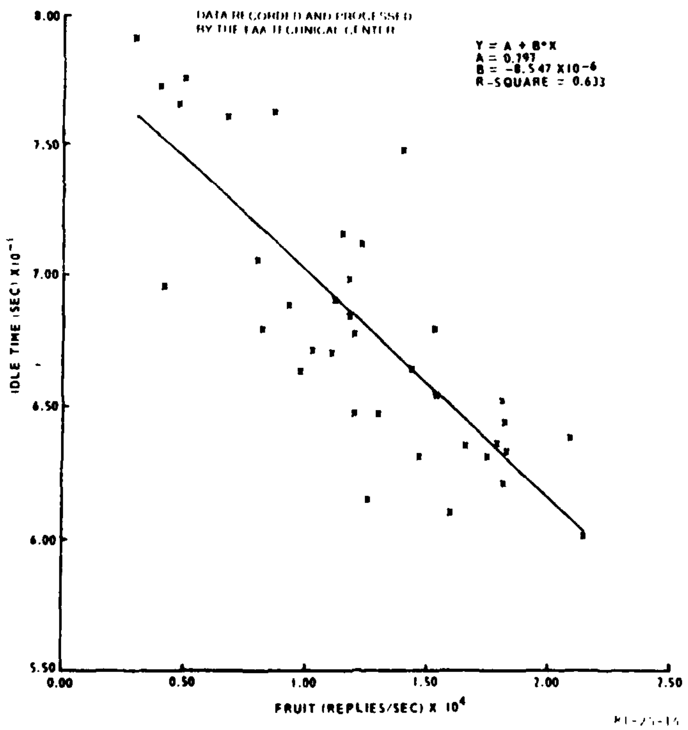


FIGURE 14. FRUIT VERSUS IDLE TIME, LOS ANGELES, JULY 20, 1980

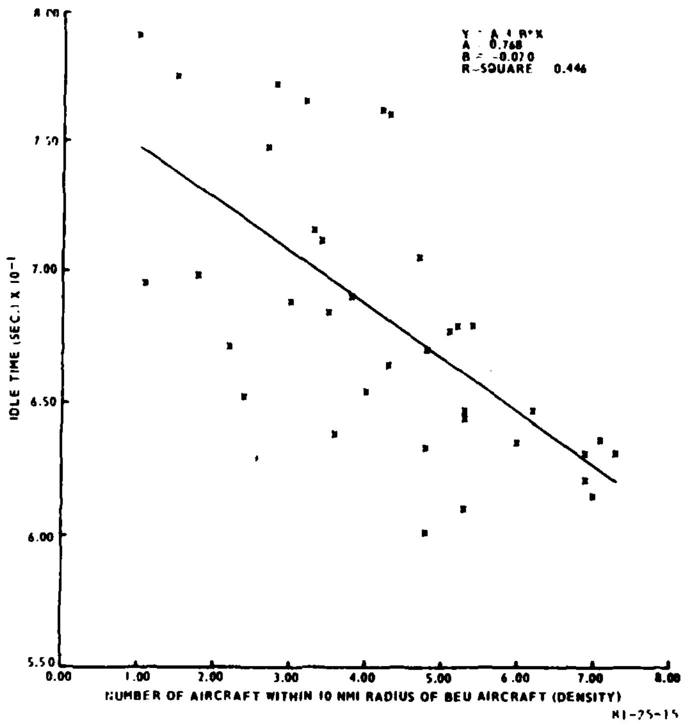


FIGURE 15. DENSITY VERSUS IDLE TIME, LOS ANGELES, JULY 20, 1980

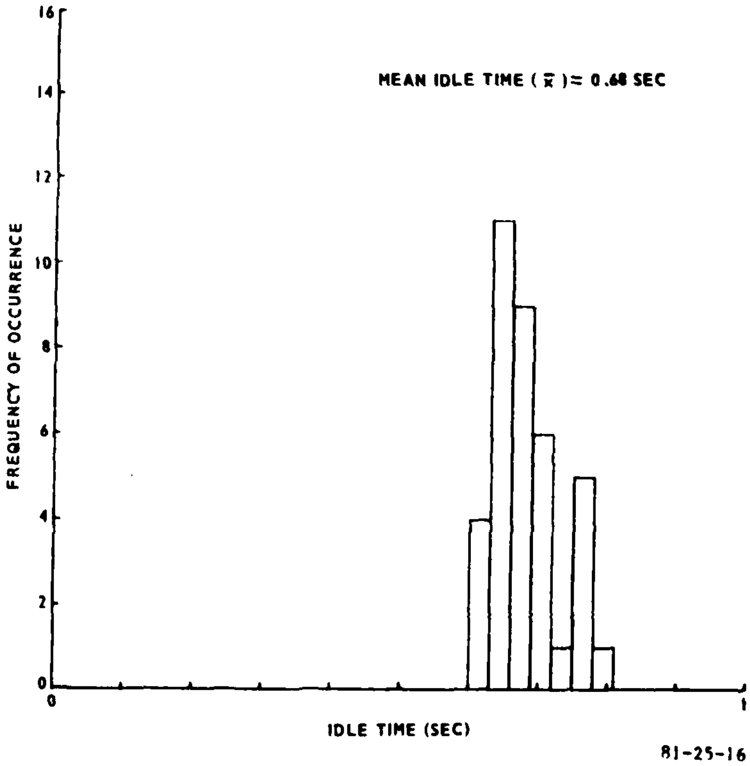


FIGURE 16. IDLE TIME HISTOGRAM, LOS ANGELES, JULY 20, 1980

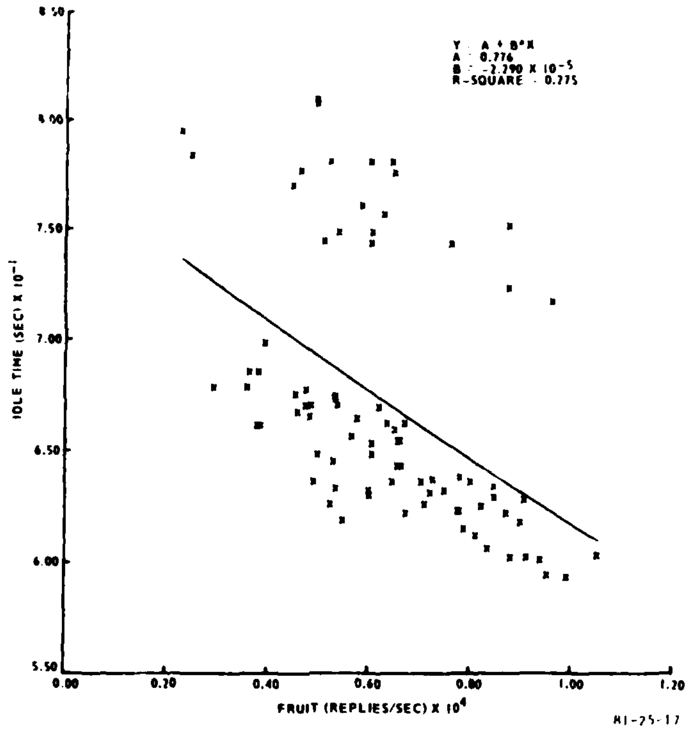


FIGURE 17. FRUIT VERSUS IDLE TIME, WASHINGTON, D.C., SEPTEMBER 8, 1980

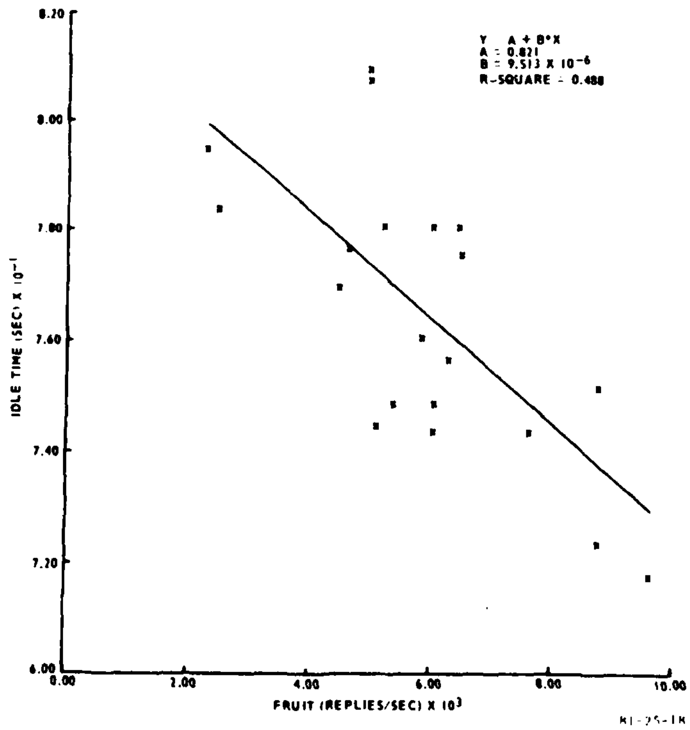


FIGURE 18. UPPER DATA GROUP OF FRUIT VERSUS IDLE TIME, SEPTEMBER 8, 1980

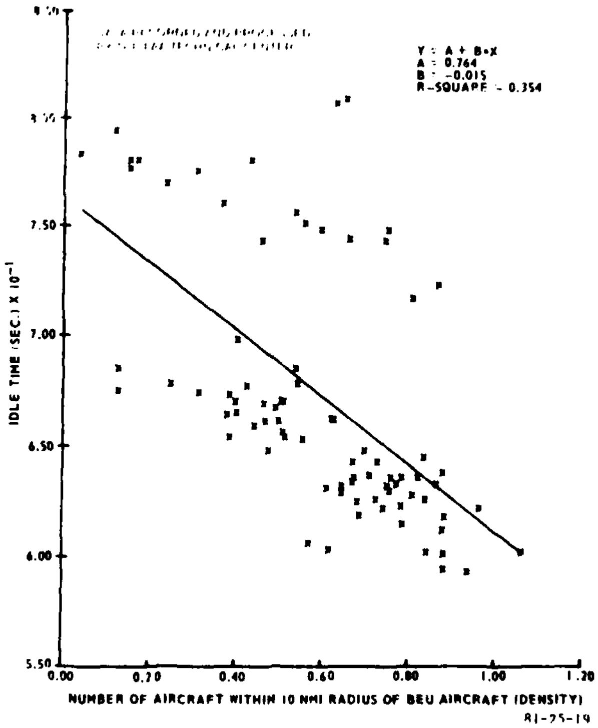


FIGURE 19. DENSITY VERUS IDLE TIME, WASHINGTON, D.C., SEPTEMBER 8, 1980

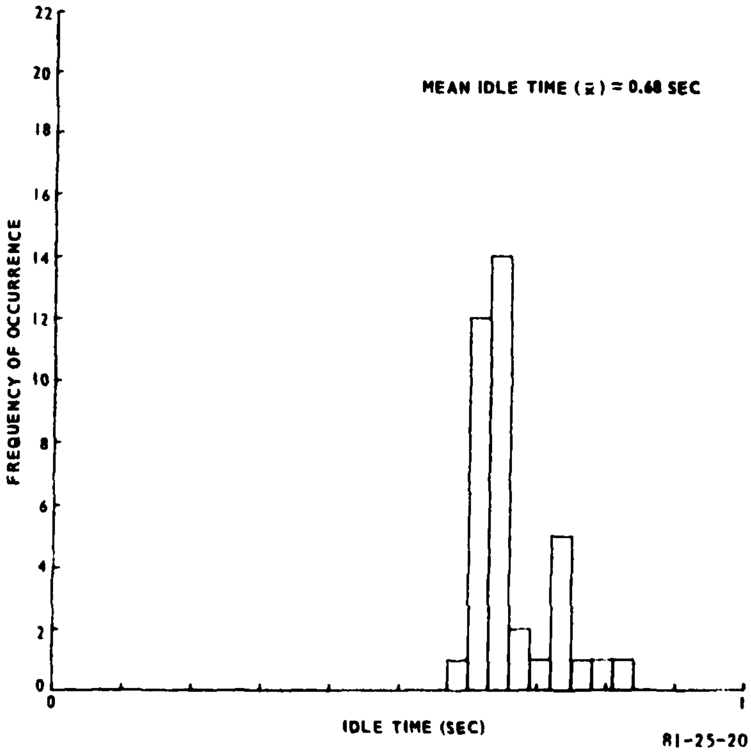


FIGURE 20. IDLE TIME HISTOGRAM, WASHINGTON, SEPTEMBER 8, 1980

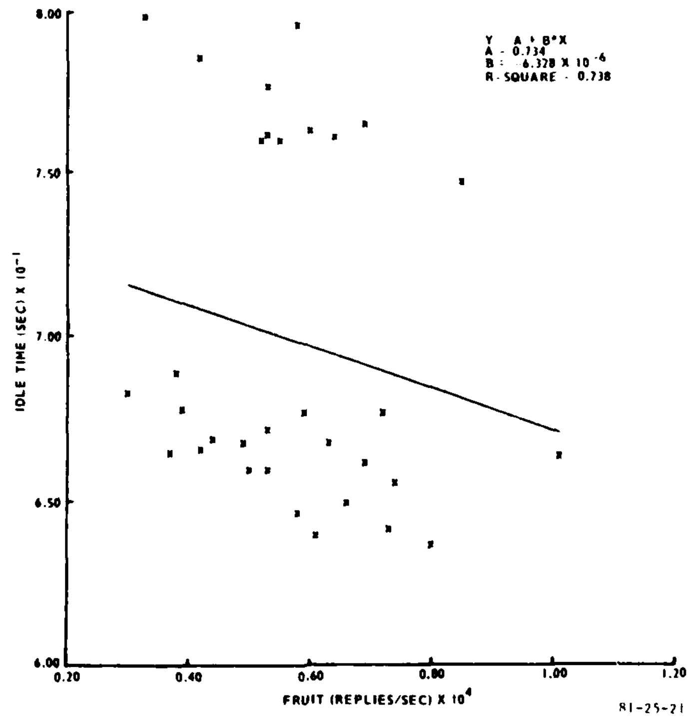


FIGURE 21. FRUIT VERSUS IDLE TIME, FAA TECHNICAL CENTER, SEPTEMBER 26, 1980

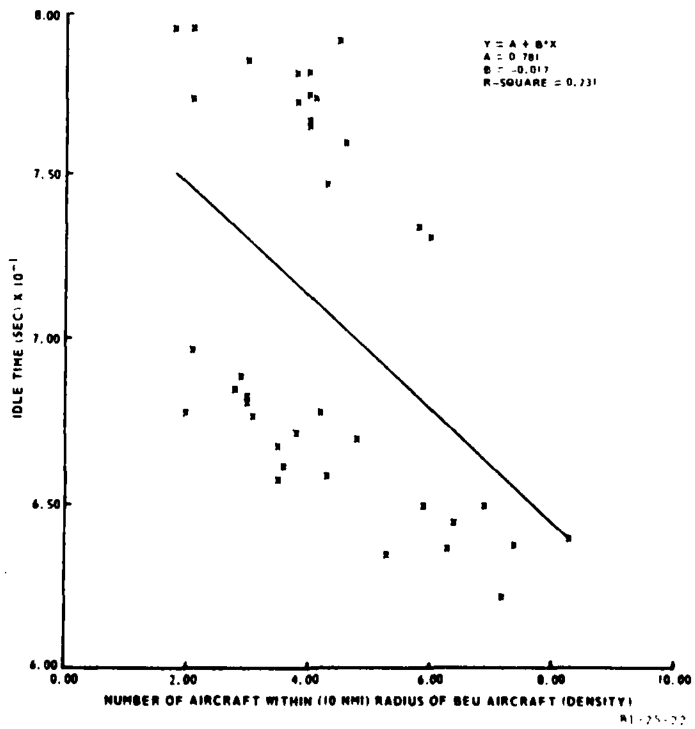


FIGURE 22. DENSITY VERSUS IDLE TIME, FAA TECHNICAL CENTER, SEPTEMBER 26, 1980

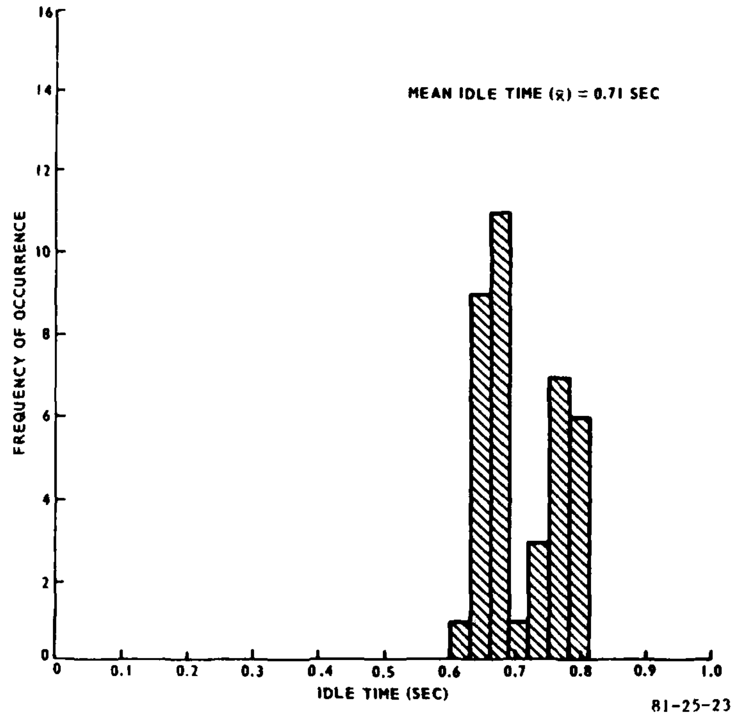


FIGURE 23. IDLE TIME HISTOGRAM, FAA TECHNICAL CENTER, SEPTEMBER 26, 1980

SELECT BEST FIT

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y A•X	0.000		8.627	-1.283	4.178
Y A + B•X	7.994	-0.000	2.956	0.218	3.114
Y A•EXP(B•X)	8.380	-0.000	3.065	0.189	3.384
Y 1/(A + B•X)	0.116	0.000	3.444	0.088	3.755
Y A + B/X	2.881	26145.819	3.105	0.178	3.293
Y A + B•LOG(X)	29.664	-2.606	3.008	0.204	3.178
Y A•X↑B	634.470	-0.519	3.140	0.169	3.501
Y X/(A + B•X)	-1124.994	0.321	3.625	0.040	3.941

EQUATION Y A + B•X HAS MAXIMUM R-SQUARE

FIGURE 24. SIMPLE REGRESSIONS, LOS ANGELES, JULY 20, 1980

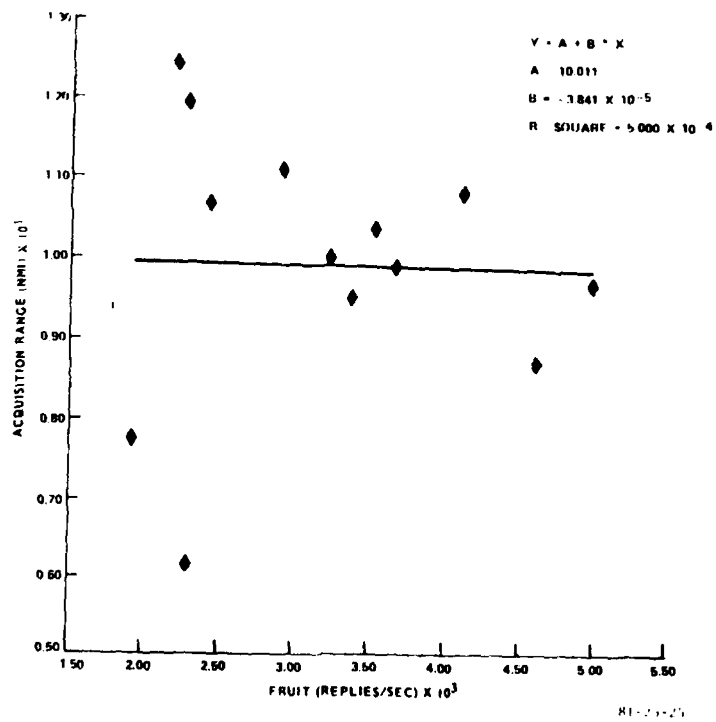


FIGURE 25. DABS ACQUISITION RANGE VERSUS FRUIT — AIRCRAFT N-49 AND N-47, OCTOBER 4, 1980

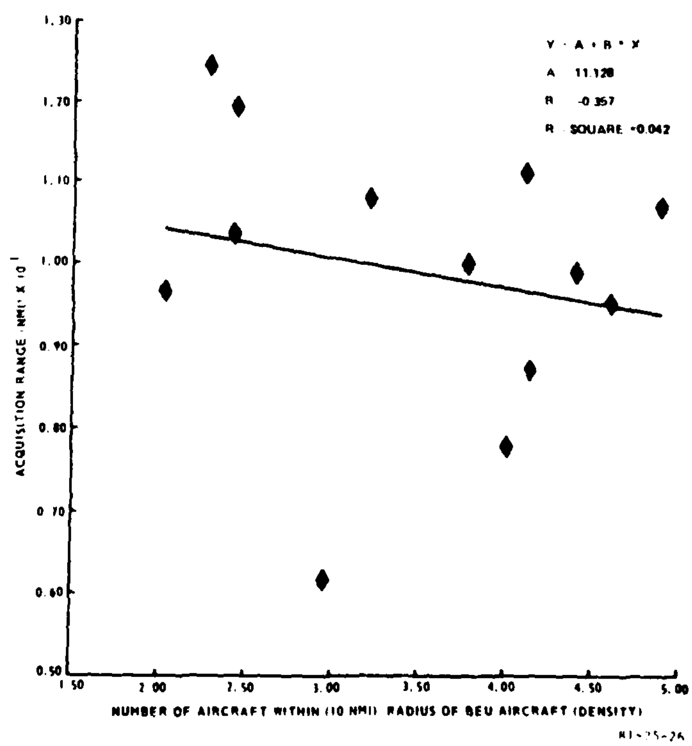


FIGURE 26. DABS ACQUISITION RANGE VERSUS DENSITY — AIRCRAFT N-49 AND N-47, OCTOBER 4, 1980

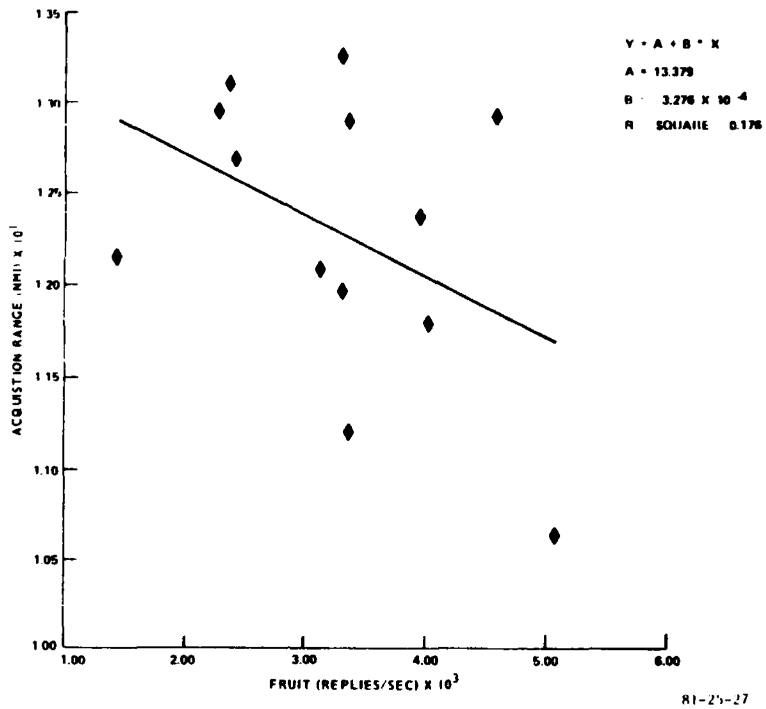


FIGURE 27. ATCRBS ACQUISITION RANGE VERSUS FRUIT — **AIRCRAFT N-49 AND N-47,** OCTOBER 4, 1980

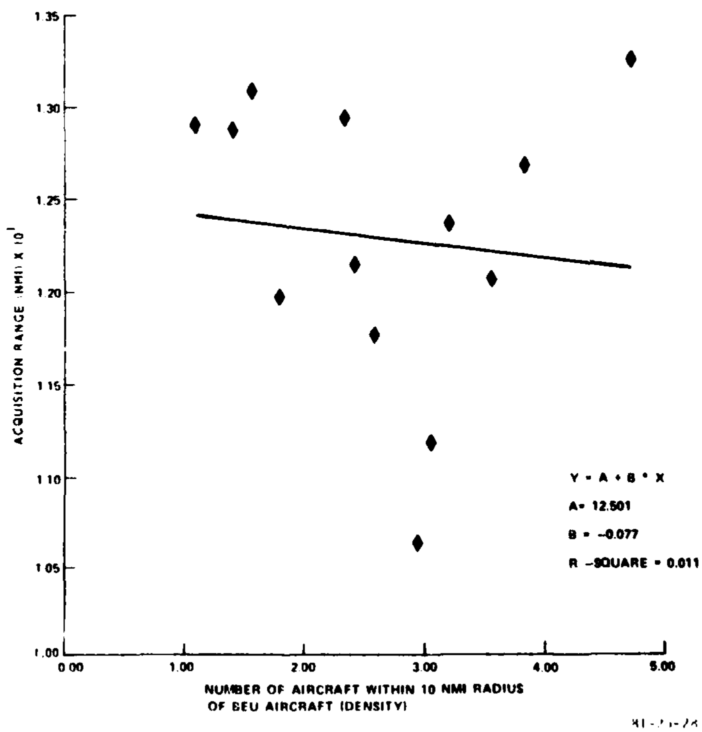


FIGURE 28. ATCRBS ACQUISITION RANGE VERSUS DENSITY — **AIRCRAFT N-49 AND N-47,** OCTOBER 4, 1980

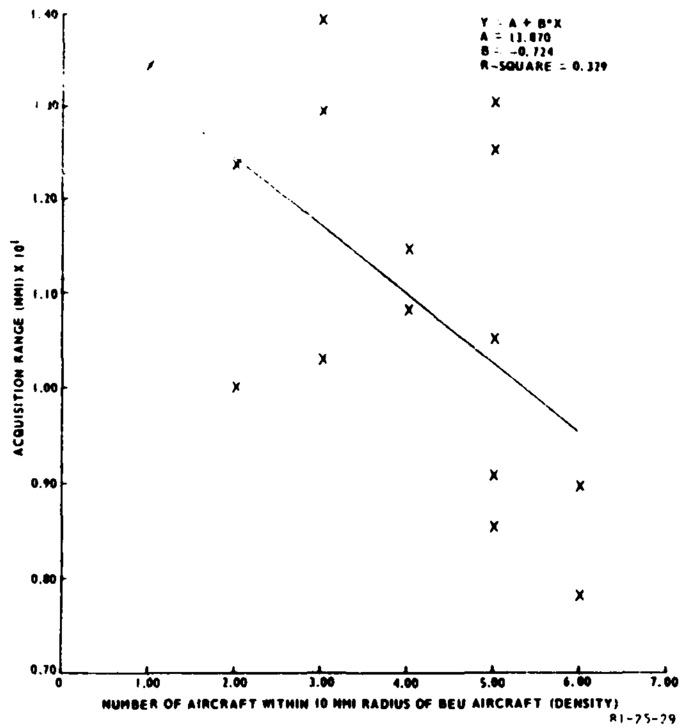


FIGURE 29. ACQUISITION RANGE VERSUS DENSITY — AIRCRAFT N-40 AND N-49, SEPTEMBER 26, 1980

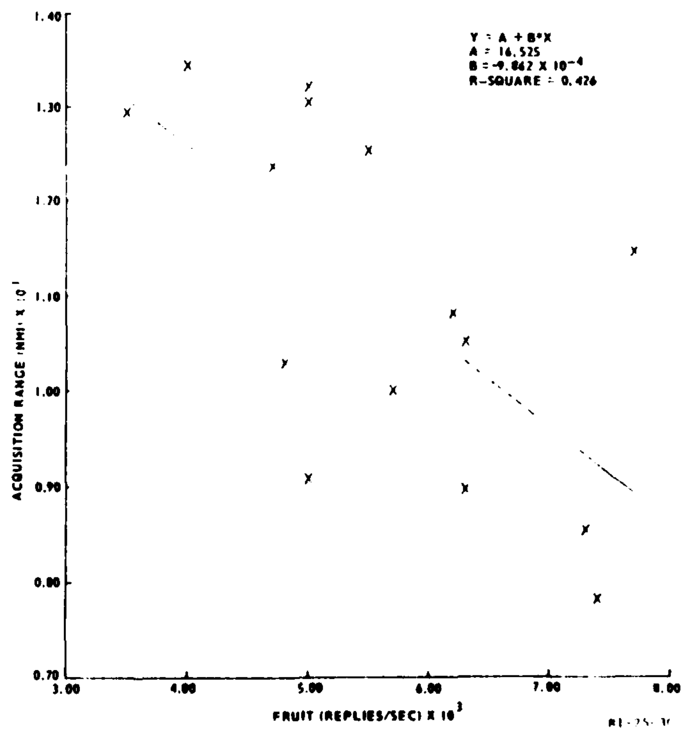


FIGURE 30. ACQUISITION RANGE VERSUS FRUIT — AIRCRAFT N-40 AND N-49, SEPTEMBER 26, 1980

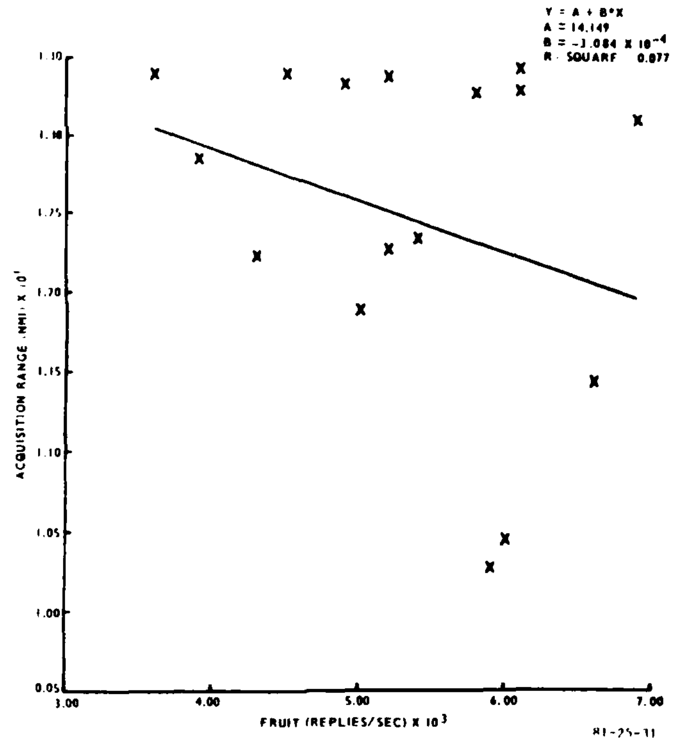


FIGURE 31. ACQUISITION RANGE VERSUS FRUIT — AIRCRAFT N-40 AND N-47, SEPTEMBER 26, 1980

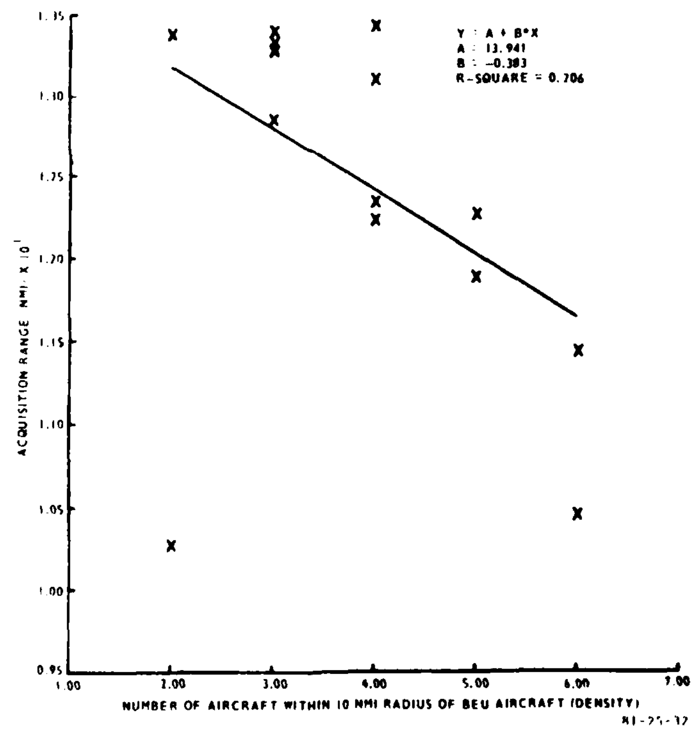


FIGURE 32. ACQUISITION RANGE VERSUS DENSITY — AIRCRAFT N-40 AND N-47, SEPTEMBER 26, 1980

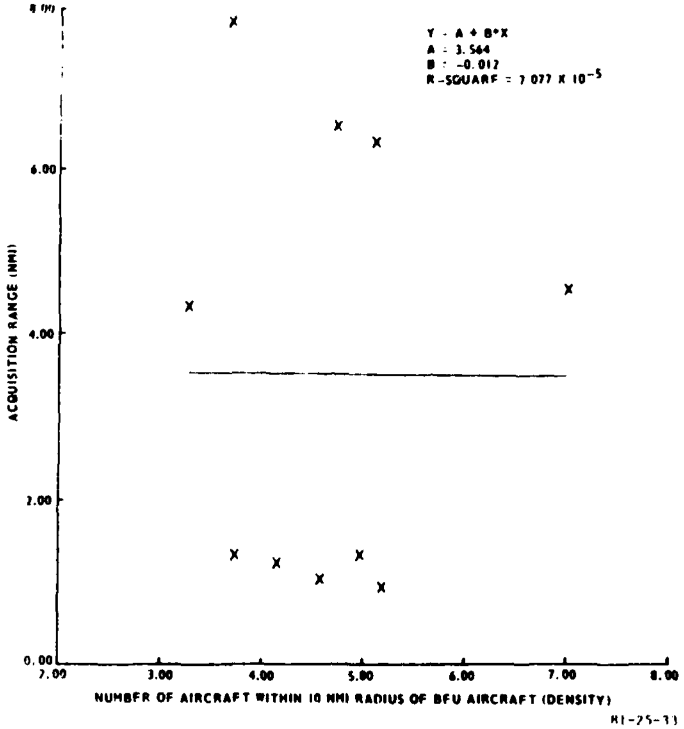


FIGURE 33. ACQUISITION RANGE VERSUS DENSITY — AIRCRAFT N-49 AND N-40, JULY 20, 1980

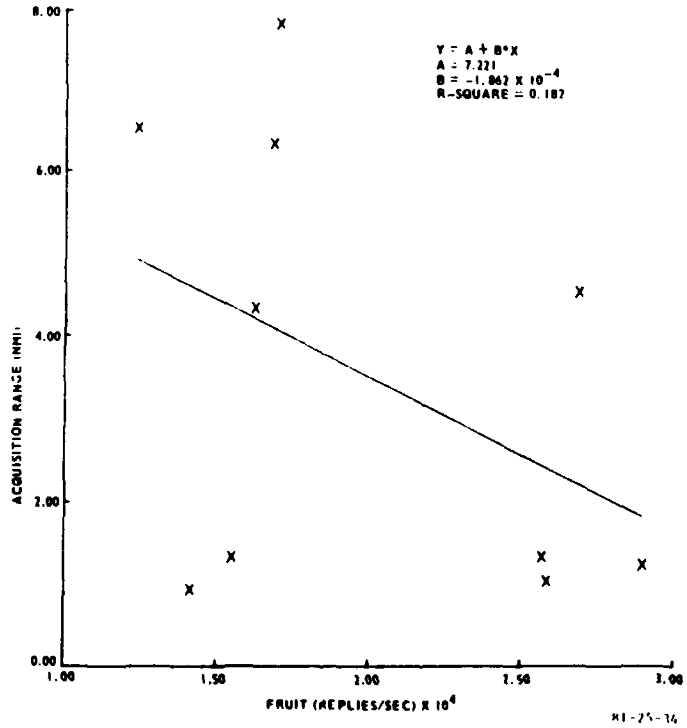


FIGURE 34. ACQUISITION RANGE VERSUS FRUIT — AIRCRAFT N-49 AND N-40, JULY 20, 1980

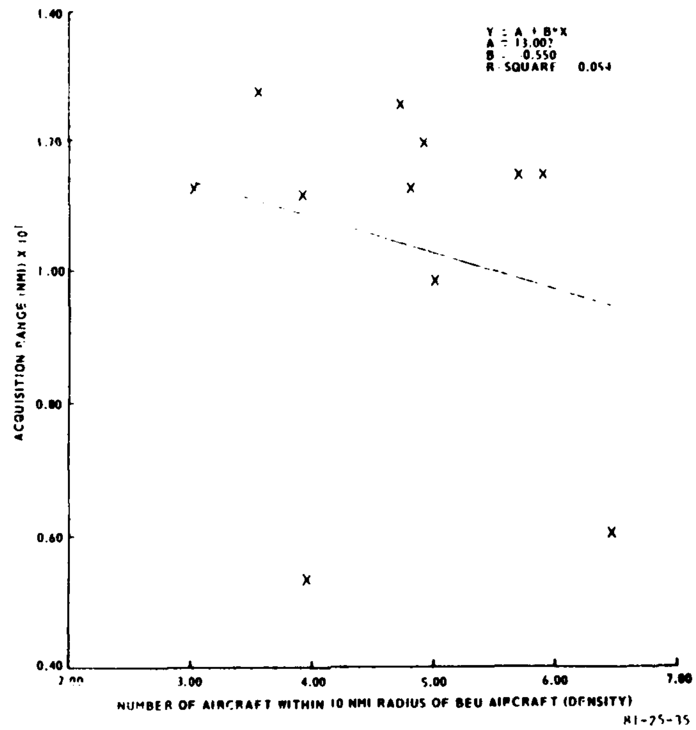


FIGURE 35. ACQUISITION RANGE VERSUS DENSITY — AIRCRAFT N-40 AND N-49, JULY 19, 1980

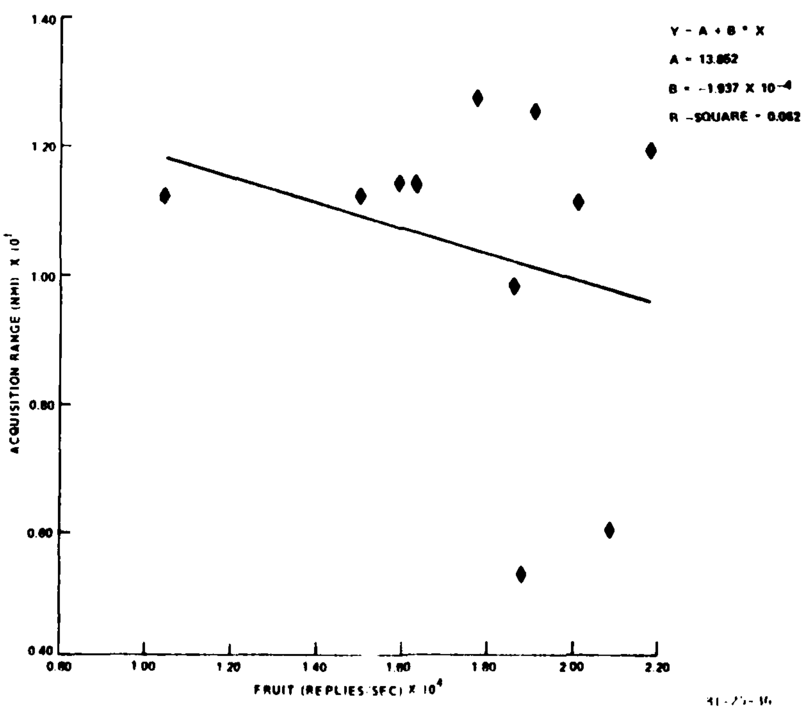


FIGURE 36. ACQUISITION RANGE VERSUS FRUIT — AIRCRAFT N-40 AND N-49, JULY 19, 1980

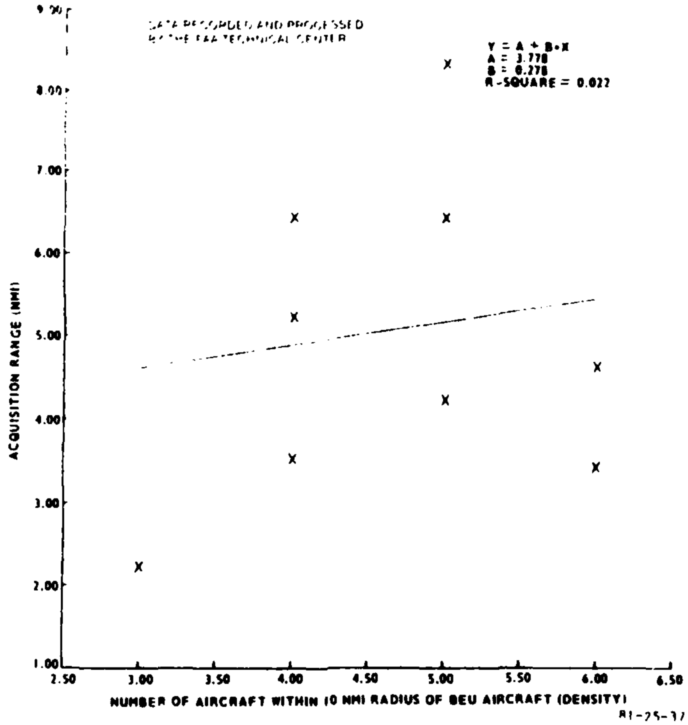


FIGURE 37. ACQUISITION RANGE VERSUS DENSITY — AIRCRAFT N-40 AND N-49, JULY 20, 1980

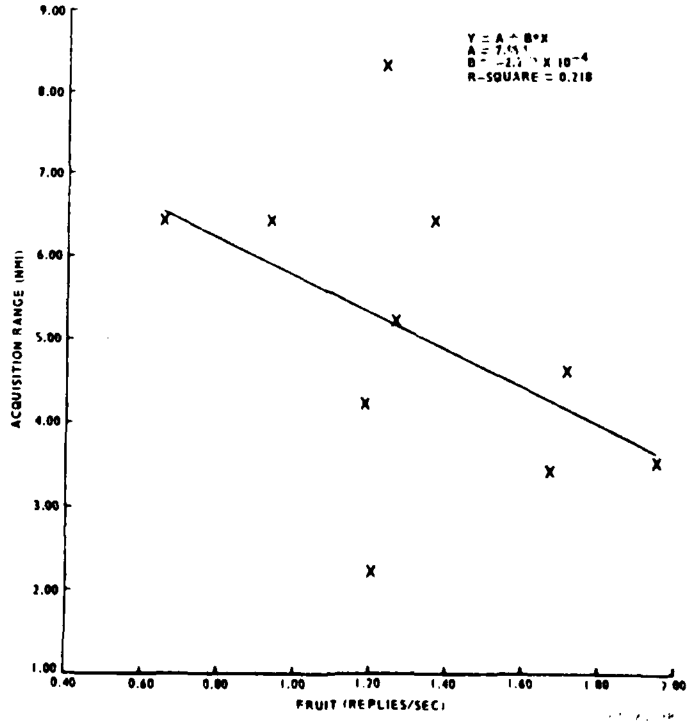


FIGURE 38. ACQUISITION RANGE VERSUS FRUIT — AIRCRAFT N-40 AND N-49, JULY 20, 1980

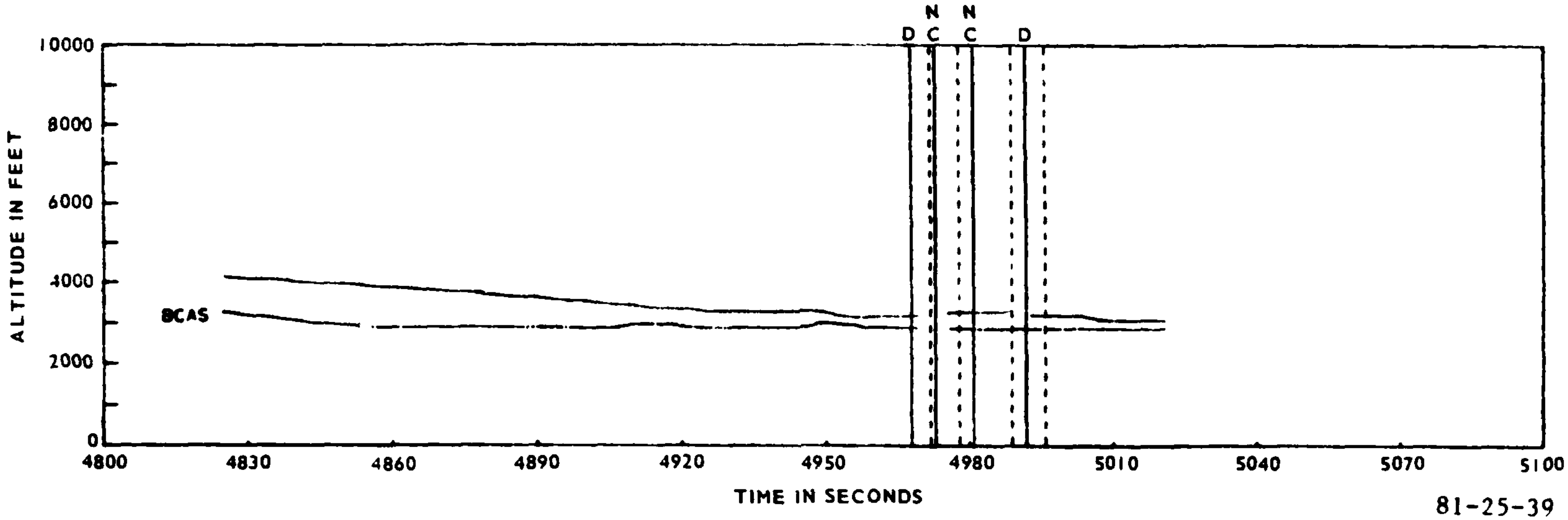


FIGURE 39. TARGET OF OPPORTUNITY (ALTITUDE), DALLAS, TEXAS, JULY 14, 1980 (D489)

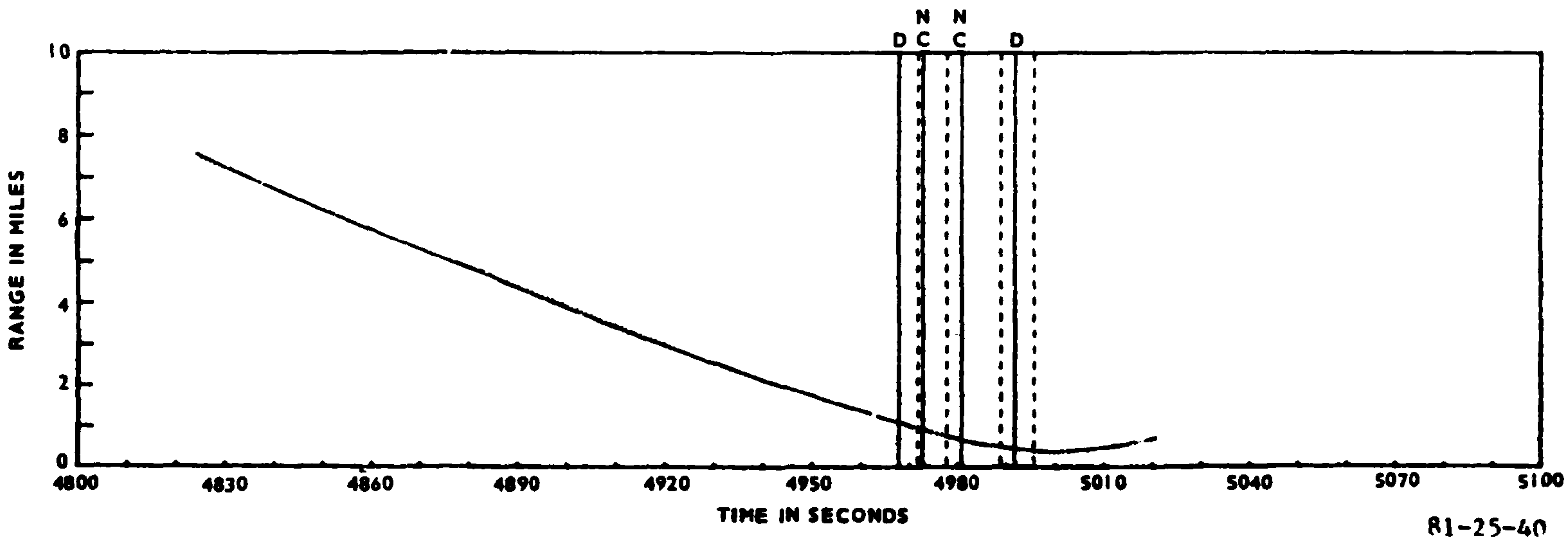


FIGURE 40. TARGET OF OPPORTUNITY (RANGE), DALLAS, TEXAS, JULY 14, 1980 (D489)

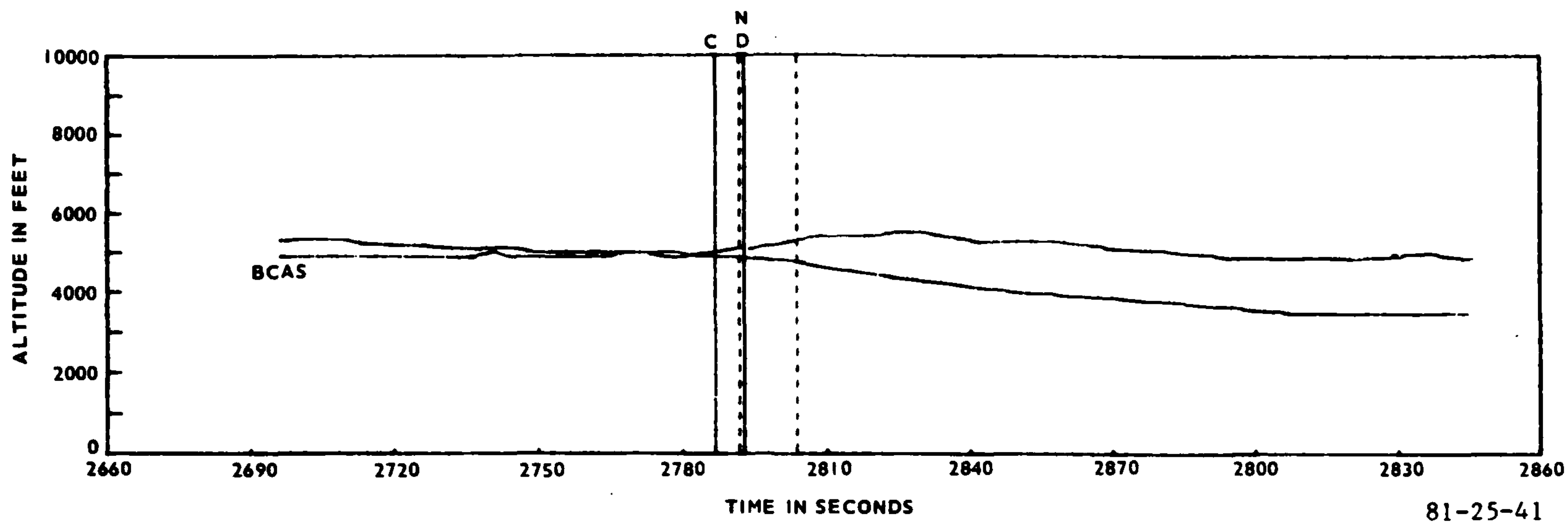


FIGURE 41. TARGET OF OPPORTUNITY (ALTITUDE), HOUSTON, TEXAS, JULY 14, 1980 (D486)

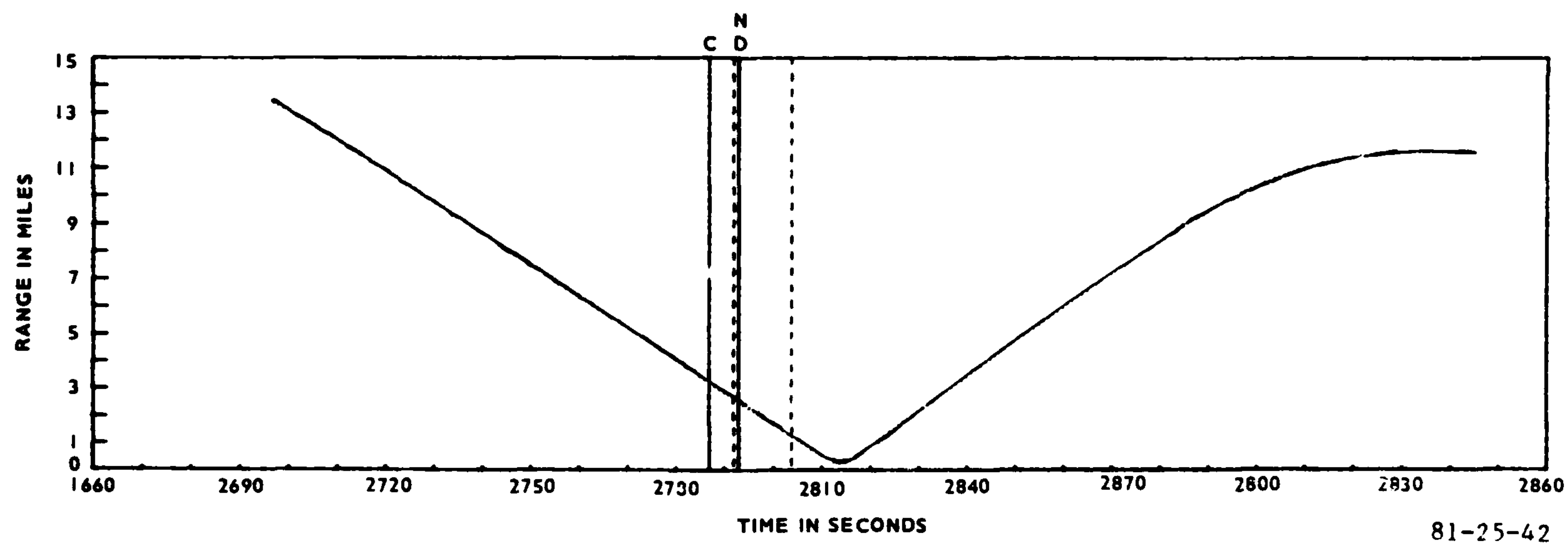


FIGURE 42. TARGET OF OPPORTUNITY (RANGE), HOUSTON, TEXAS, JULY 14, 1980 (D486)

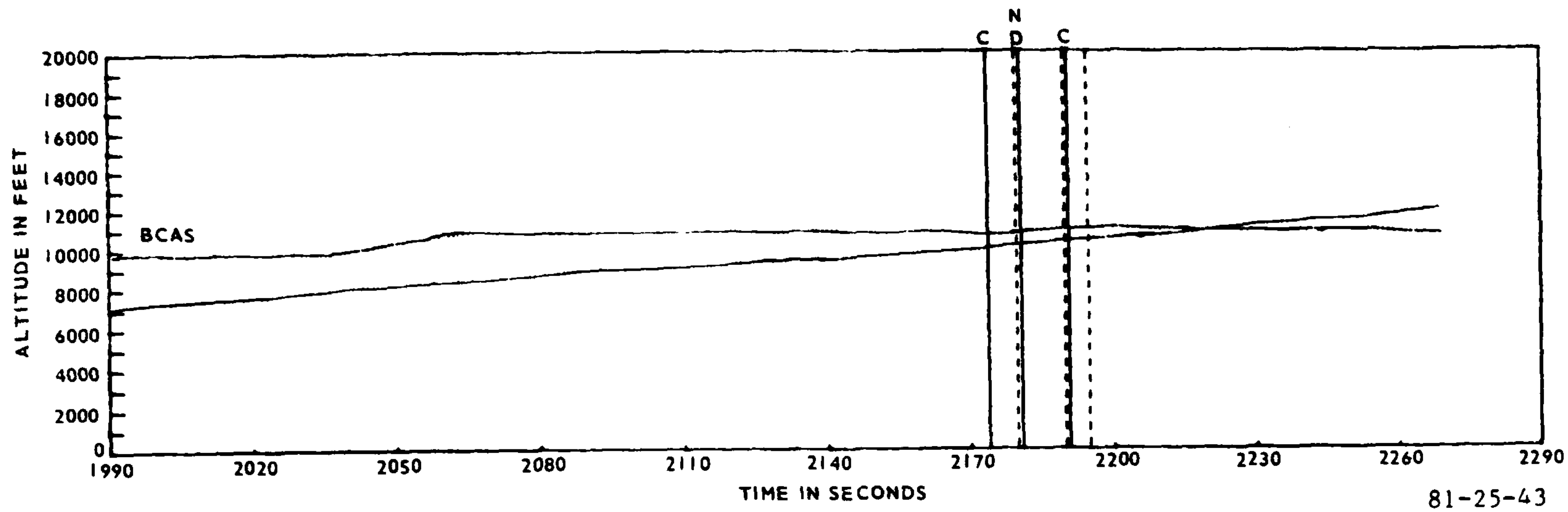


FIGURE 43. TARGET OF OPPORTUNITY (ALTITUDE, ENCOUNTER 1), DENVER, COLORADO, JULY 15, 1980 (D487)

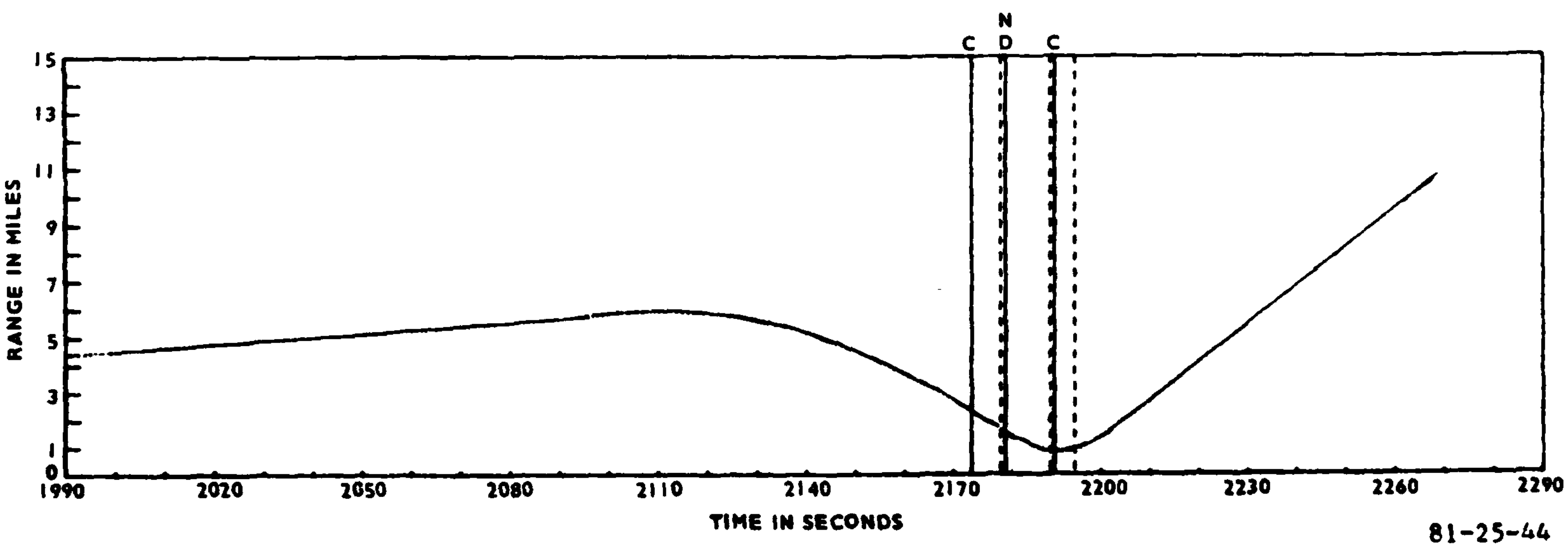


FIGURE 44. TARGET OF OPPORTUNITY (RANGE, ENCOUNTER 1), DENVER, COLORADO, JULY 15, 1980 (D487)

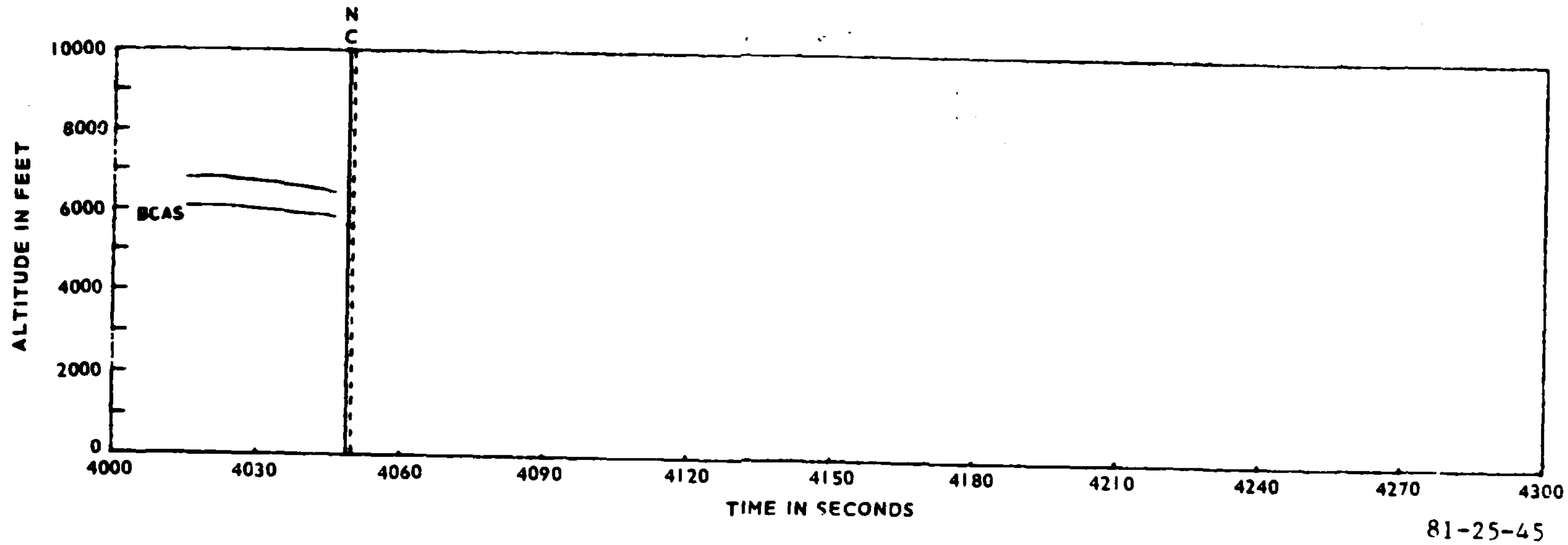


FIGURE 45. TARGET OF OPPORTUNITY (ALTITUDE, ENCOUNTER 2), DENVER, COLORADO, JULY 15, 1980 (D487)

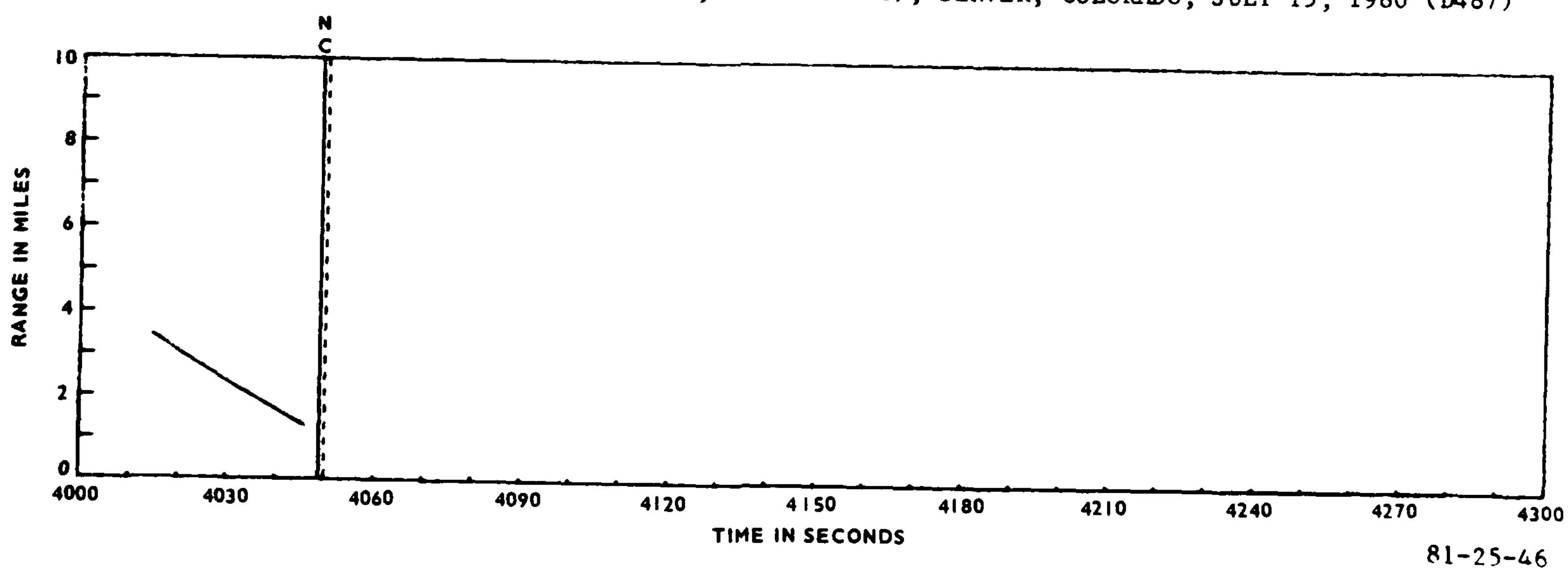


FIGURE 46. TARGET OF OPPORTUNITY (RANGE, ENCOUNTER 2), DENVER, COLORADO, JULY 15, 1980 (D487)

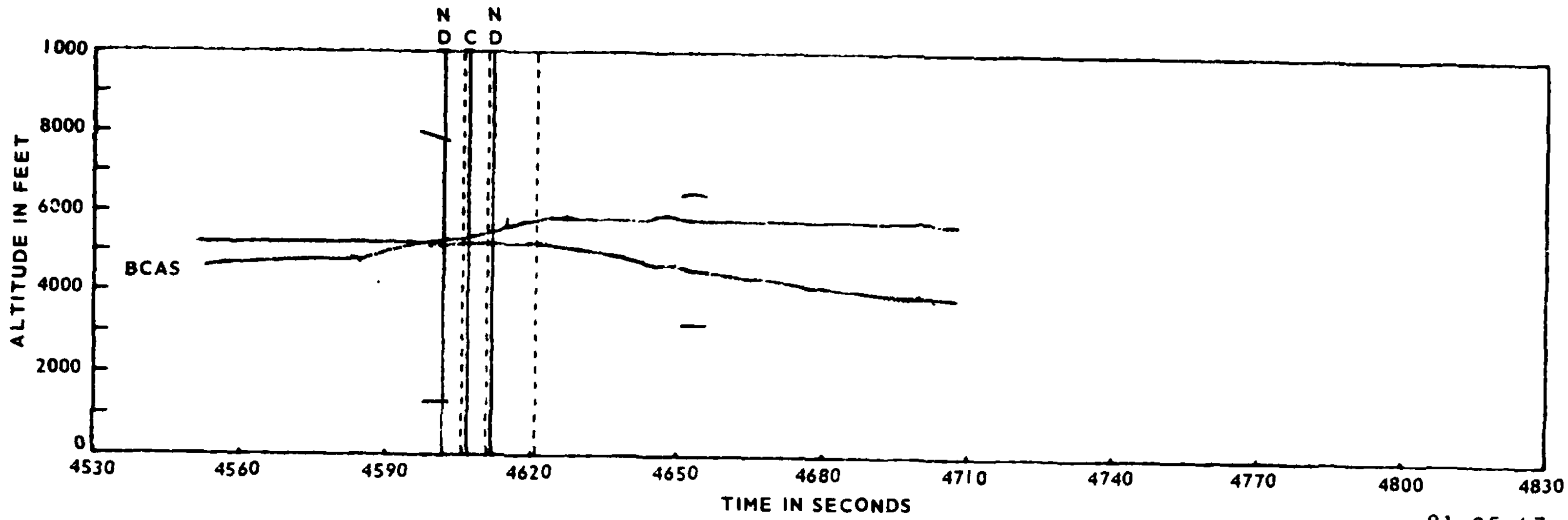


FIGURE 47. TARGET OF OPPORTUNITY (ALTITUDE), SALT LAKE CITY, UTAH, JULY 16, 1980 (D496)

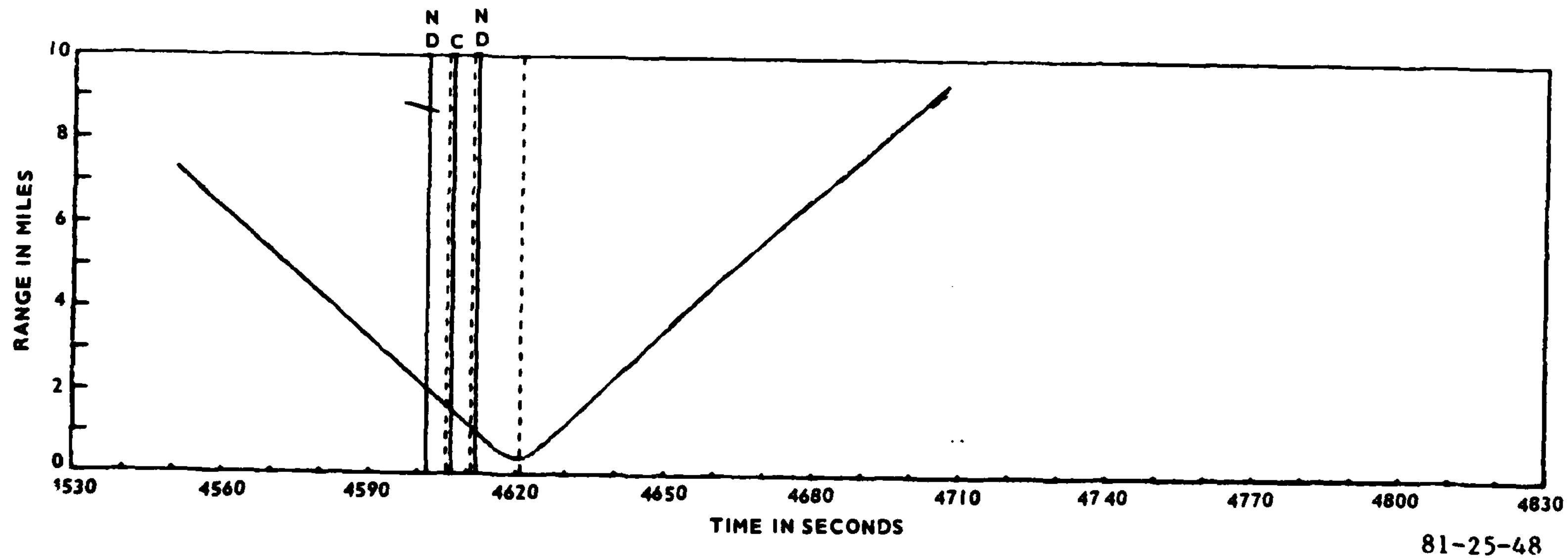


FIGURE 48. TARGET OF OPPORTUNITY (RANGE), SALT LAKE CITY, UTAH, JULY 16, 1980 (D496)

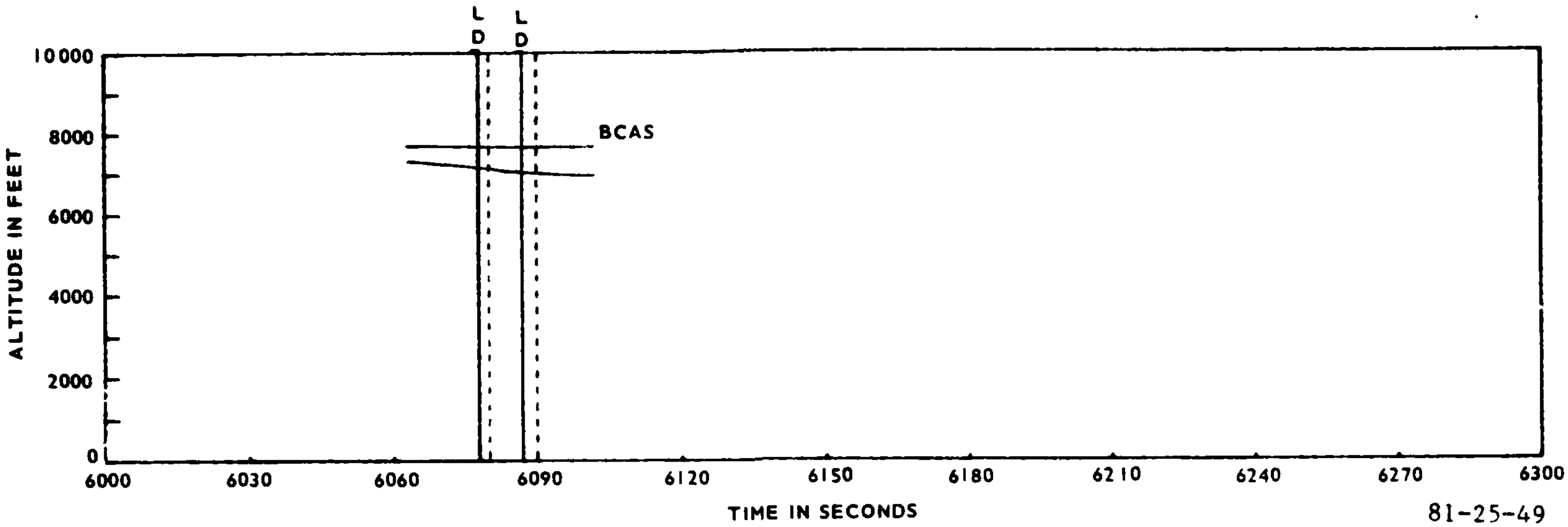


FIGURE 49. TARGET OF OPPORTUNITY (ALTITUDE), LOS ANGELES, CALIFORNIA, JULY 18, 1989 (D483)

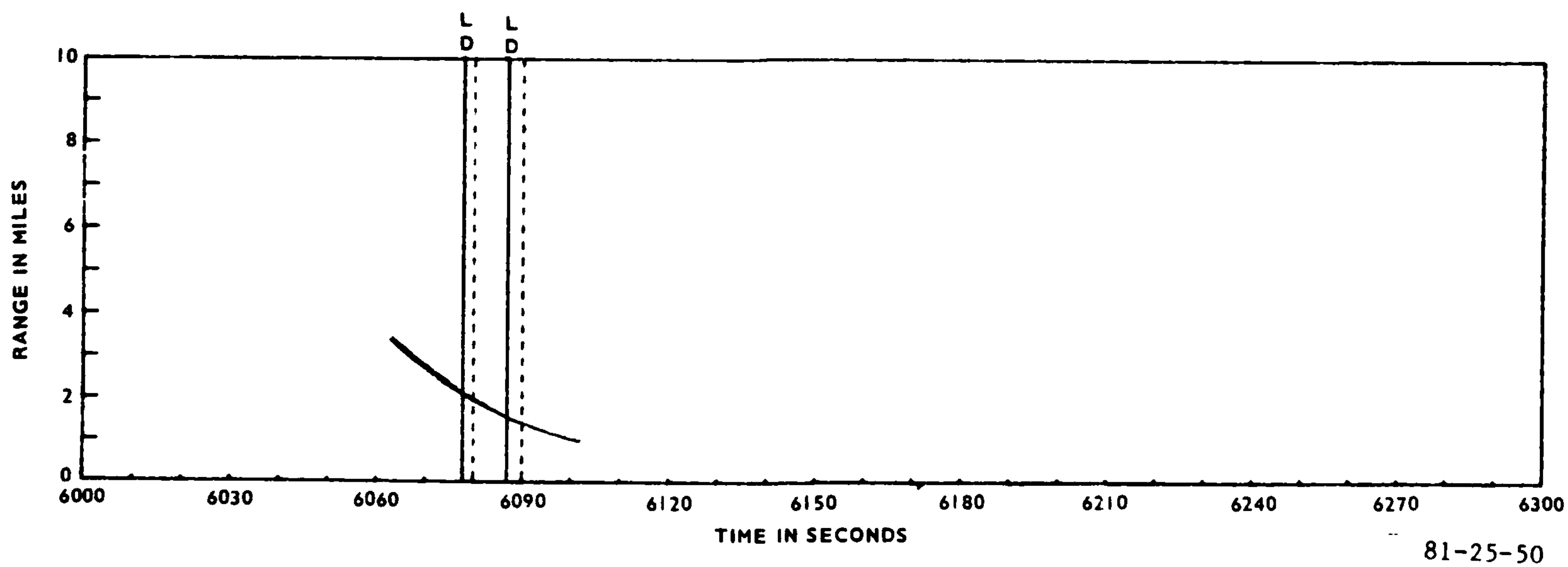
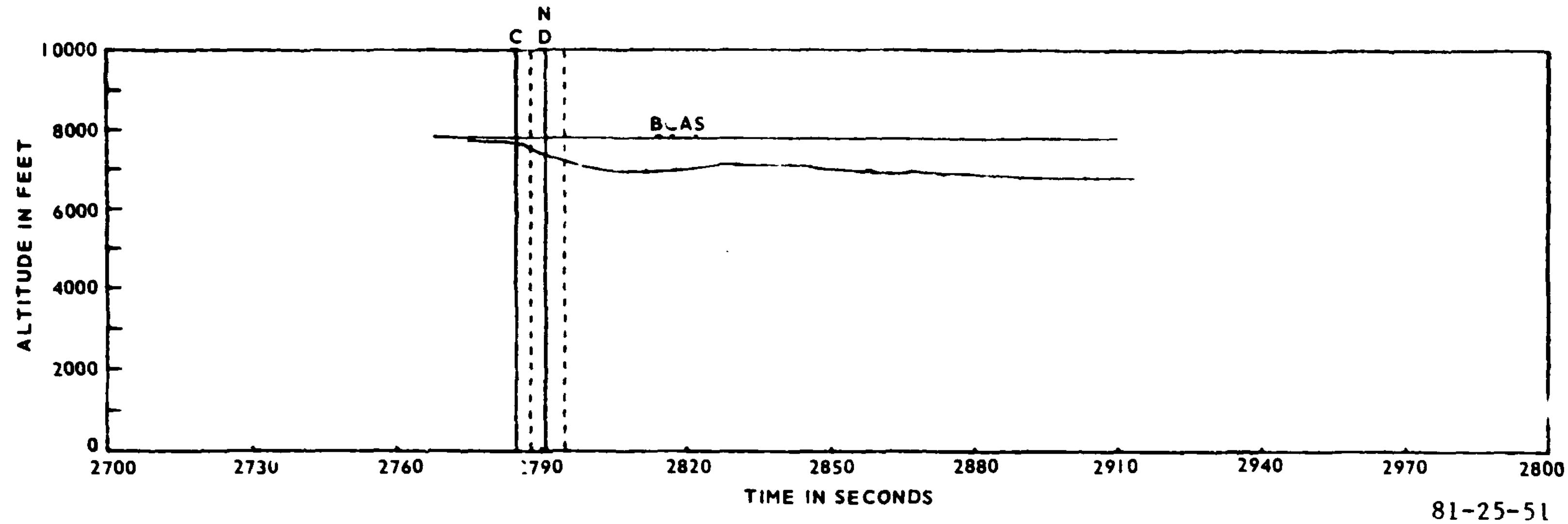
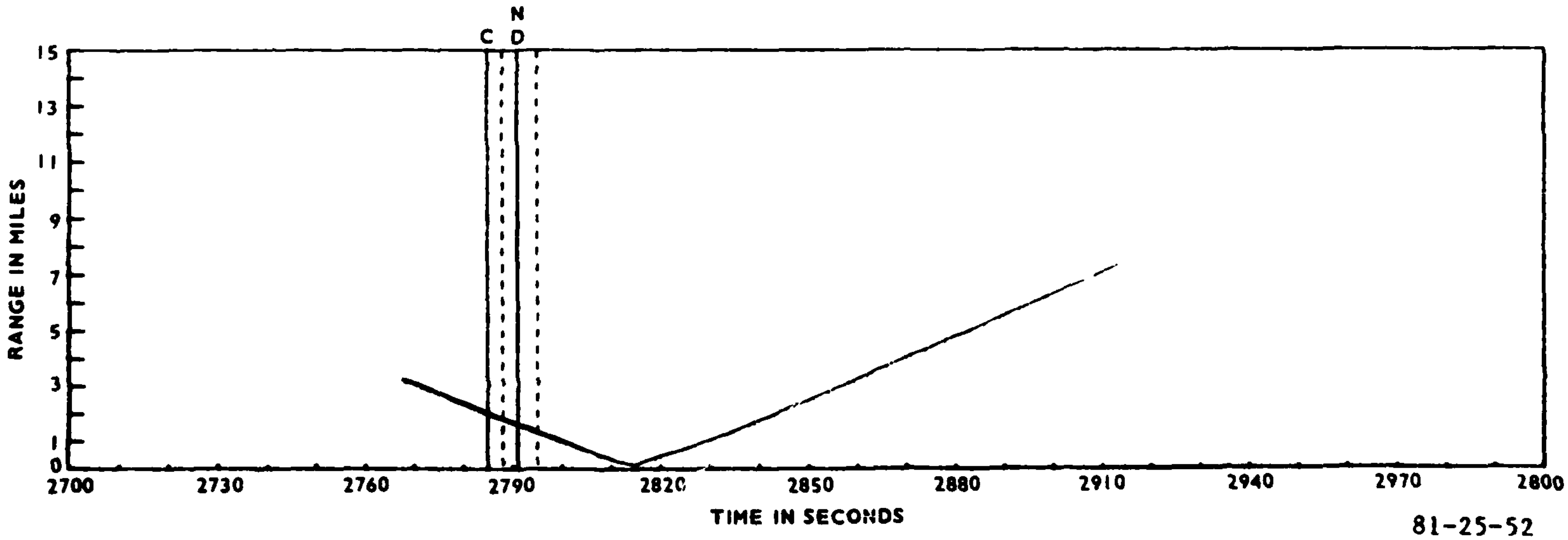


FIGURE 50. TARGET OF OPPORTUNITY (RANGE), LOS ANGELES, CALIFORNIA, JULY 18, 1980 (D483)



81-25-51

FIGURE 51. TARGET OF OPPORTUNITY (ALTITUDE, ENCOUNTER 1), LOS ANGELES, CALIFORNIA, JULY 19, 1980 (D482)



81-25-52

FIGURE 52. TARGET OF OPPORTUNITY (RANGE, ENCOUNTER 1), LOS ANGELES, CALIFORNIA, JULY 19, 1980 (D482)

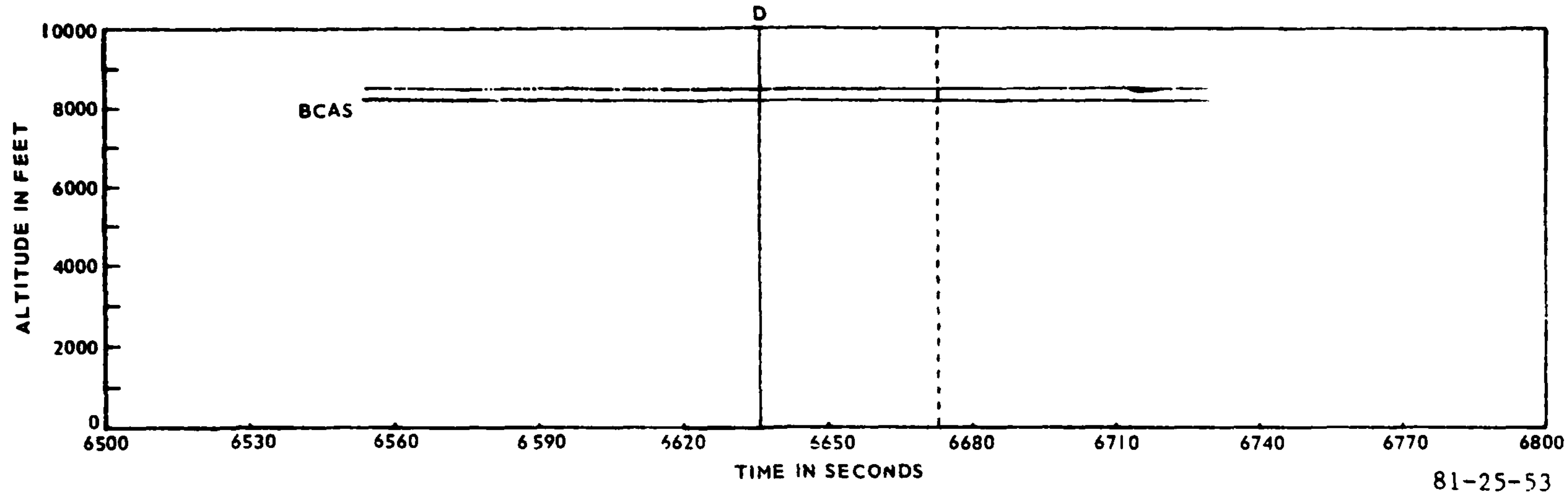


FIGURE 53. TARGET OF OPPORTUNITY (ALTITUDE, ENCOUNTER 2), LOS ANGELES, CALIFORNIA, JULY 19, 1980 (D482)

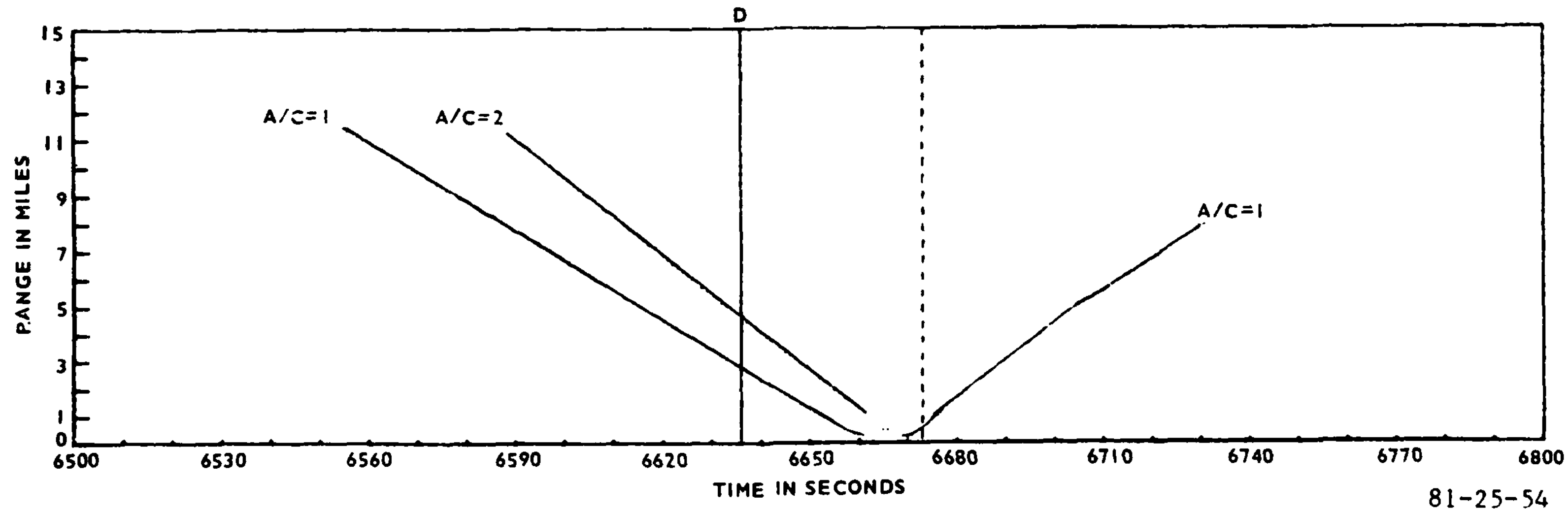


FIGURE 54. TARGET OF OPPORTUNITY (RANGE, ENCOUNTER 2), LOS ANGELES, CALIFORNIA, JULY 19, 1980 (D482)

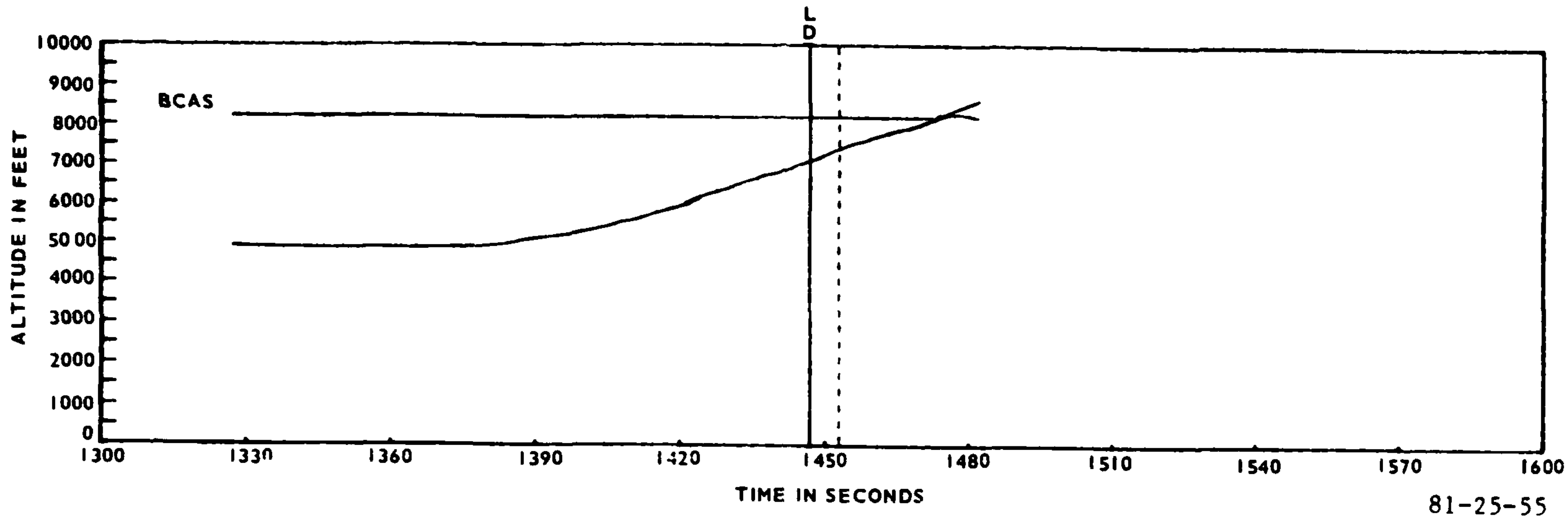


FIGURE 55. TARGET OF OPPORTUNITY (ALTITUDE), LOS ANGELES, CALIFORNIA, JULY 20, 1980 (D479)

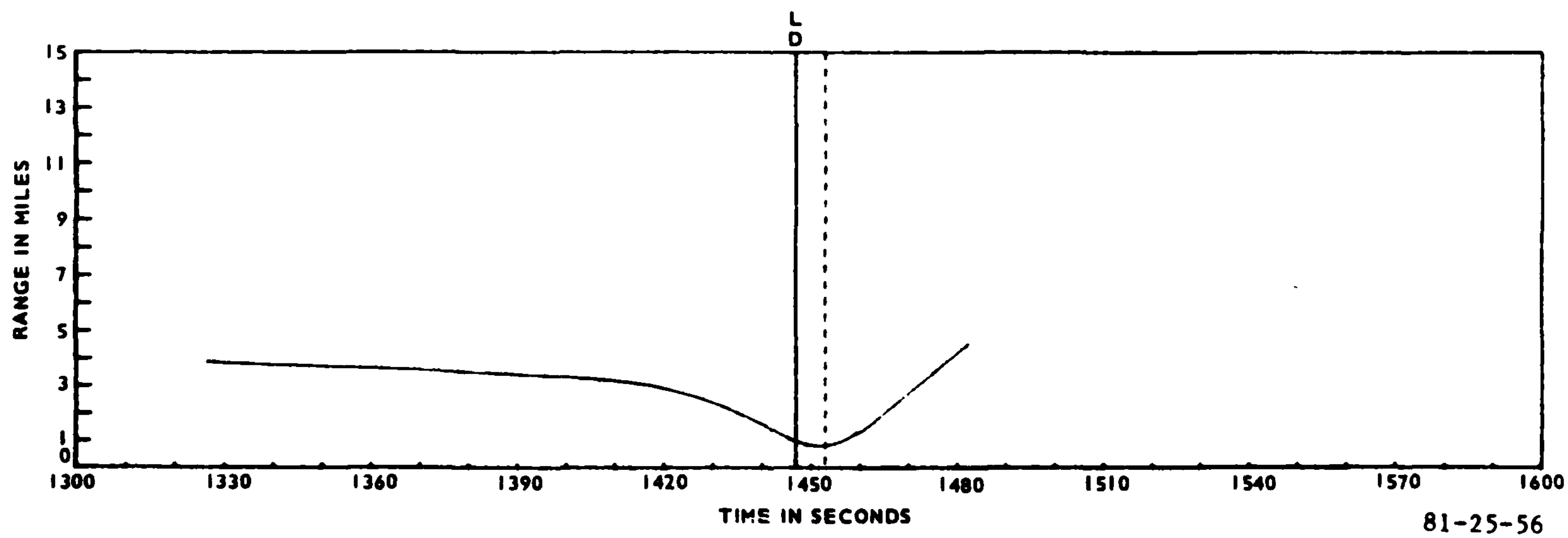


FIGURE 56. TARGET OF OPPORTUNITY (RANGE), LOS ANGELES, CALIFORNIA, JULY 20, 1980 (D479)

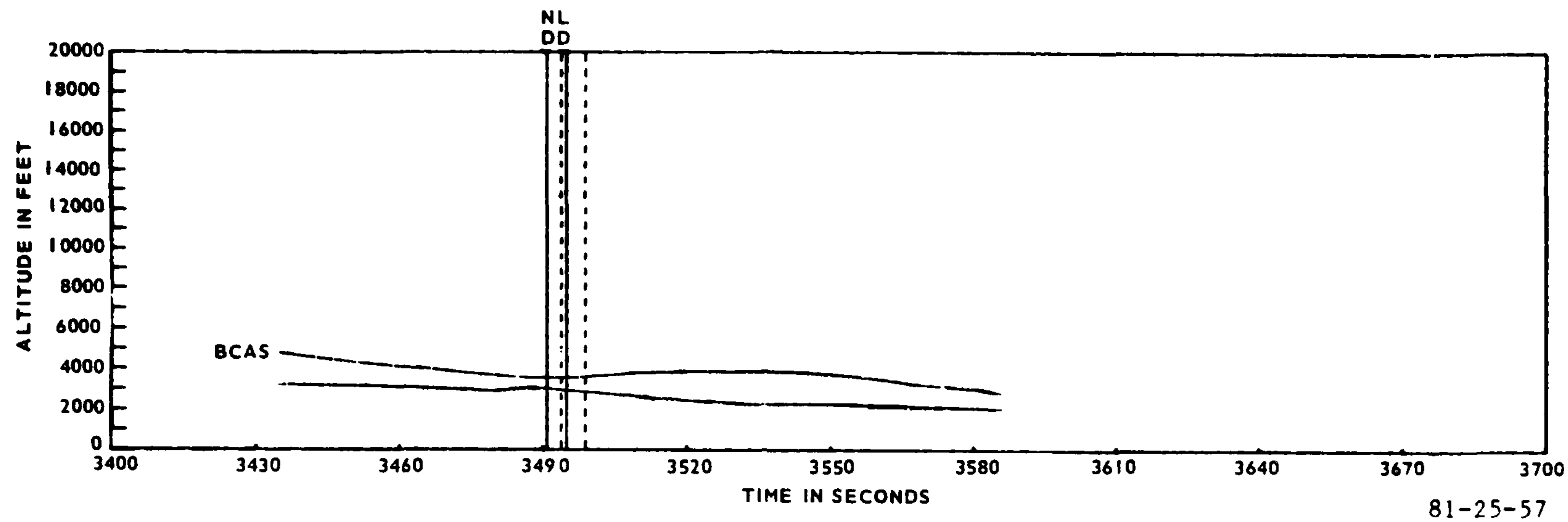


FIGURE 57. TARGET OF OPPORTUNITY (ALTITUDE), SEATTLE, WASHINGTON, JULY 23, 1980 (D490)

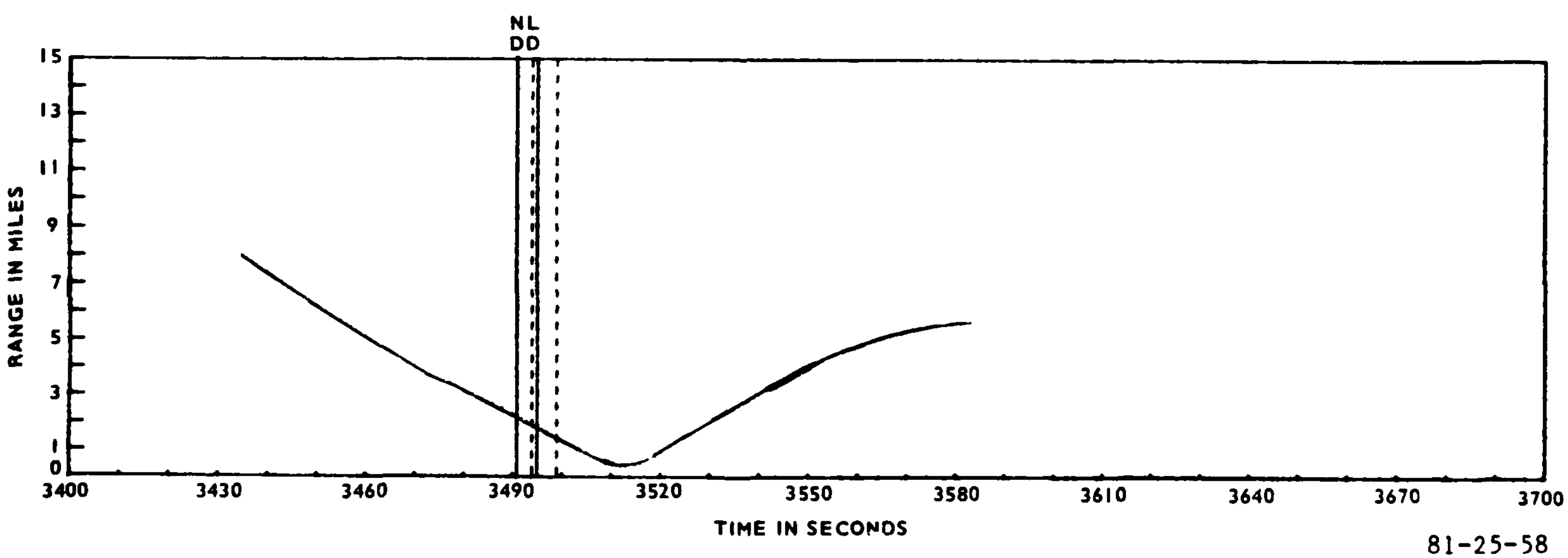


FIGURE 58. TARGET OF OPPORTUNITY (RANGE), SEATTLE, WASHINGTON, JULY 23, 1980 (D490)

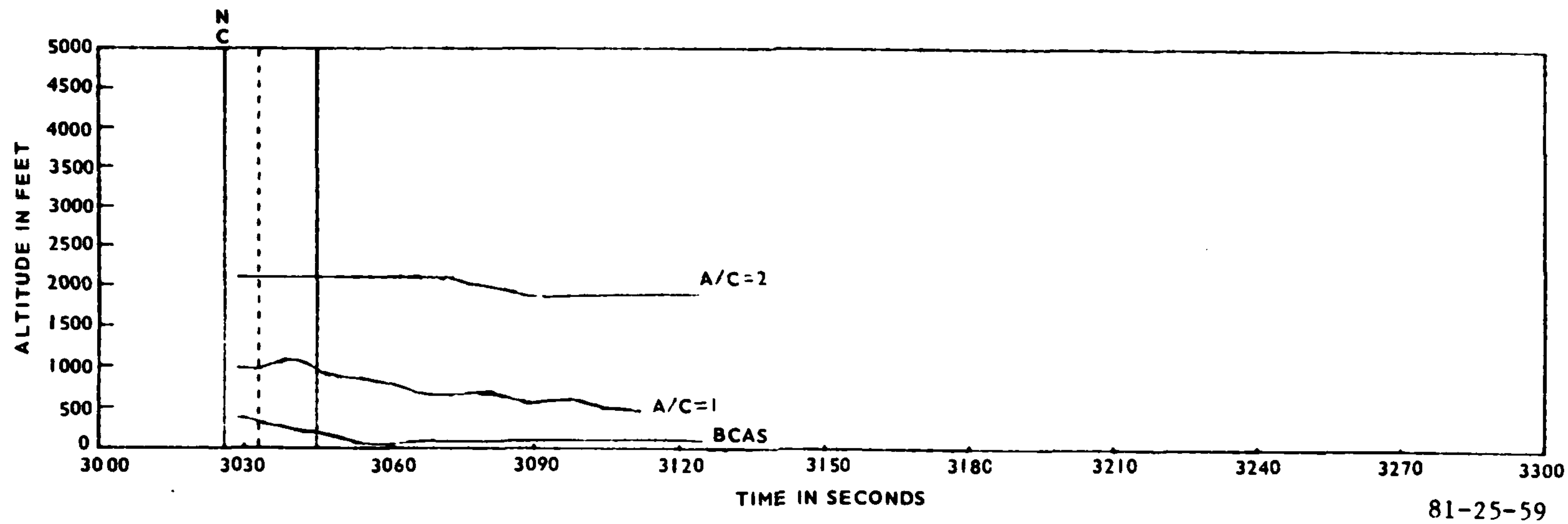


FIGURE 59. TARGET OF OPPORTUNITY (ALTITUDE, ENCOUNTER 1), SAN FRANCISCO, CALIFORNIA, JULY 24, 1980 (Y328)

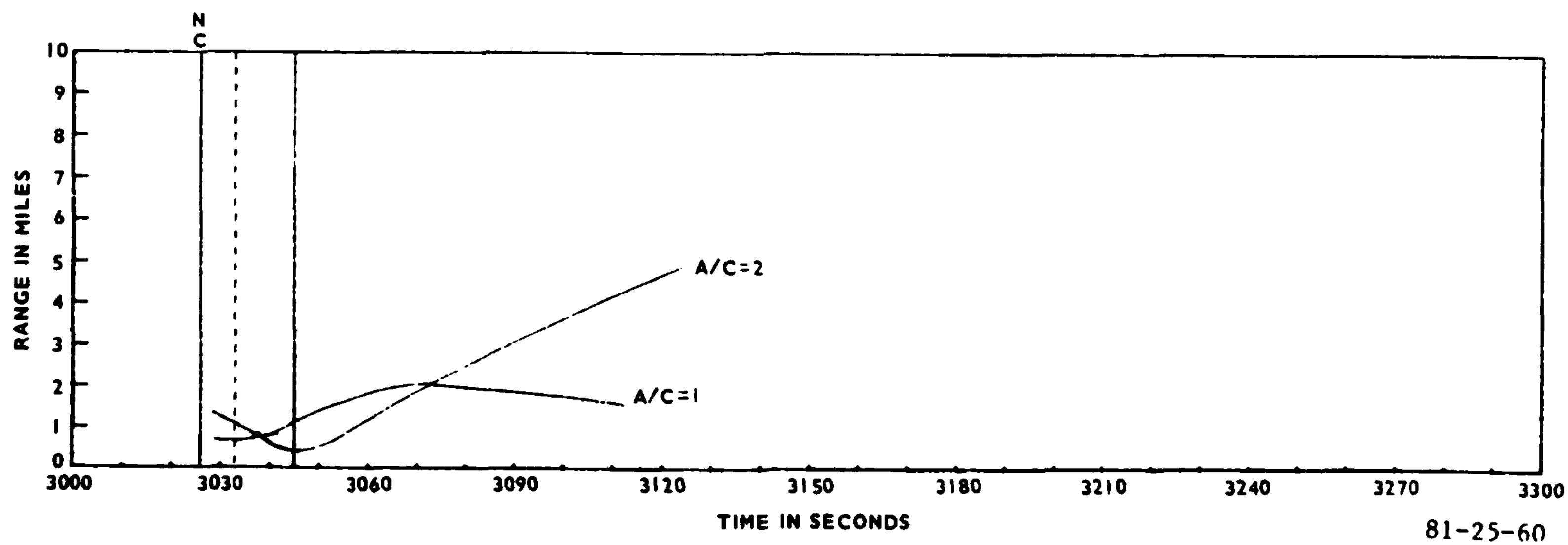


FIGURE 60. TARGET OF OPPORTUNITY (RANGE, ENCOUNTER 1), SAN FRANCISCO, CALIFORNIA, JULY 24, 1980 (Y328)

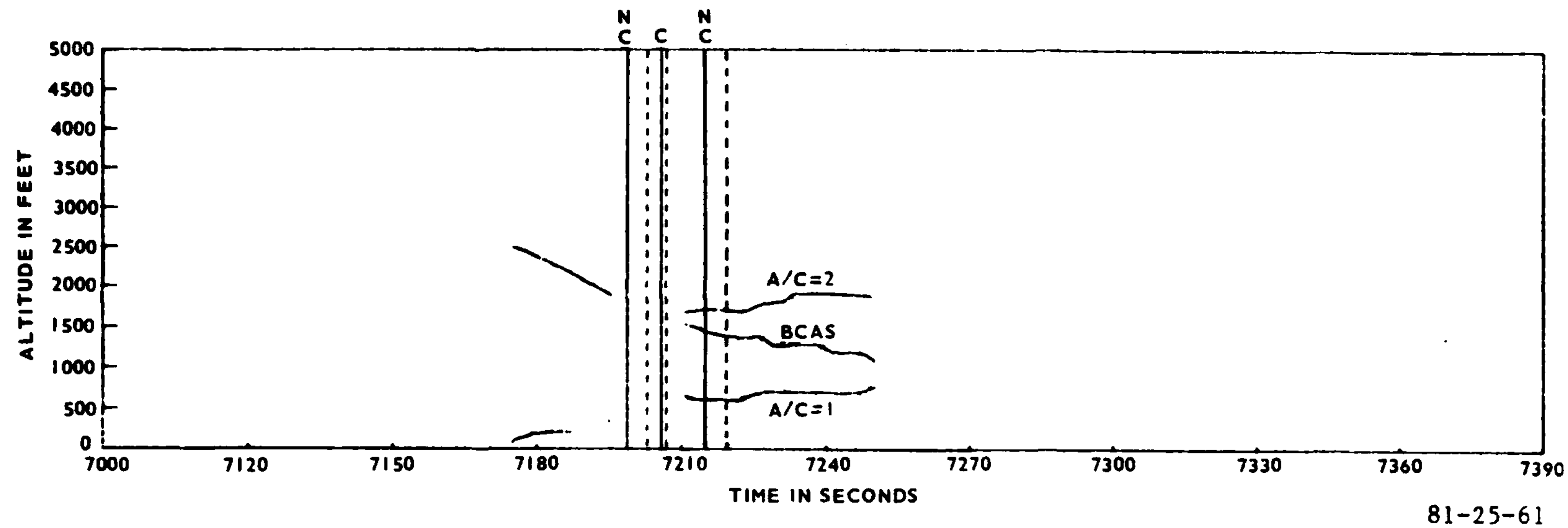


FIGURE 61. TARGET OF OPPORTUNITY (ALTITUDE, ENCOUNTER 2), SAN FRANCISCO, CALIFORNIA, JULY 24, 1980 (Y328)

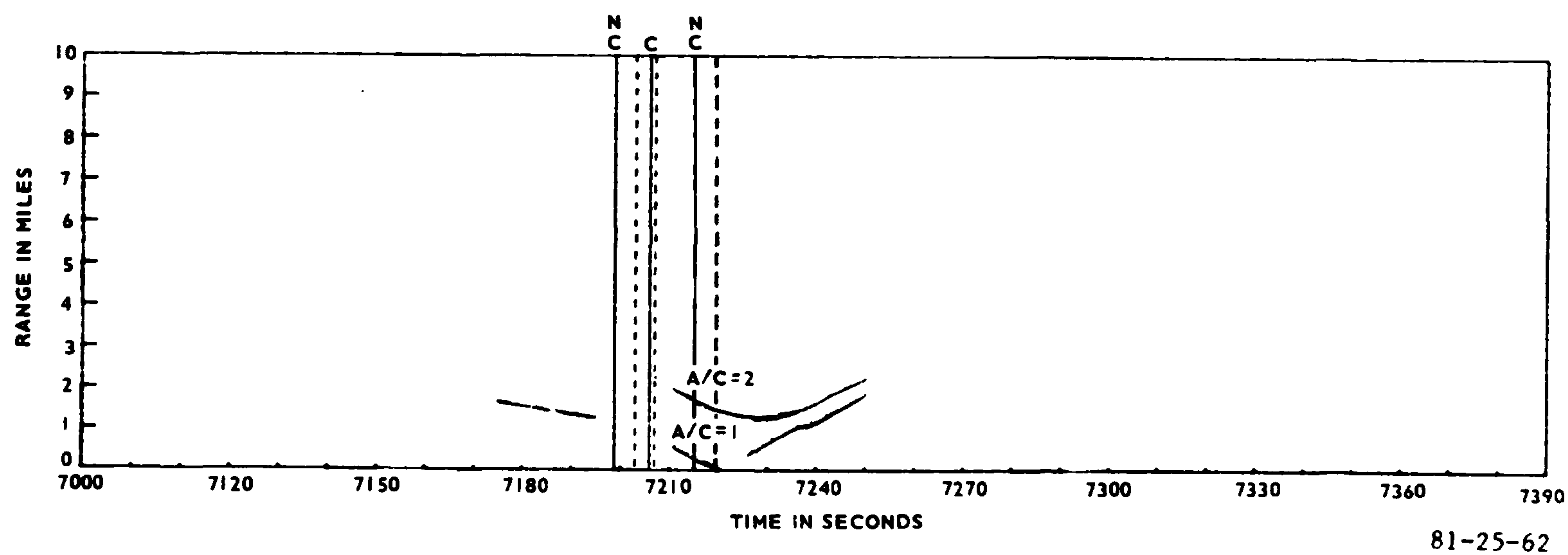


FIGURE 62. TARGET OF OPPORTUNITY (RANGE, ENCOUNTER 2), SAN FRANCISCO, CALIFORNIA, JULY 24, 1980 (Y328)

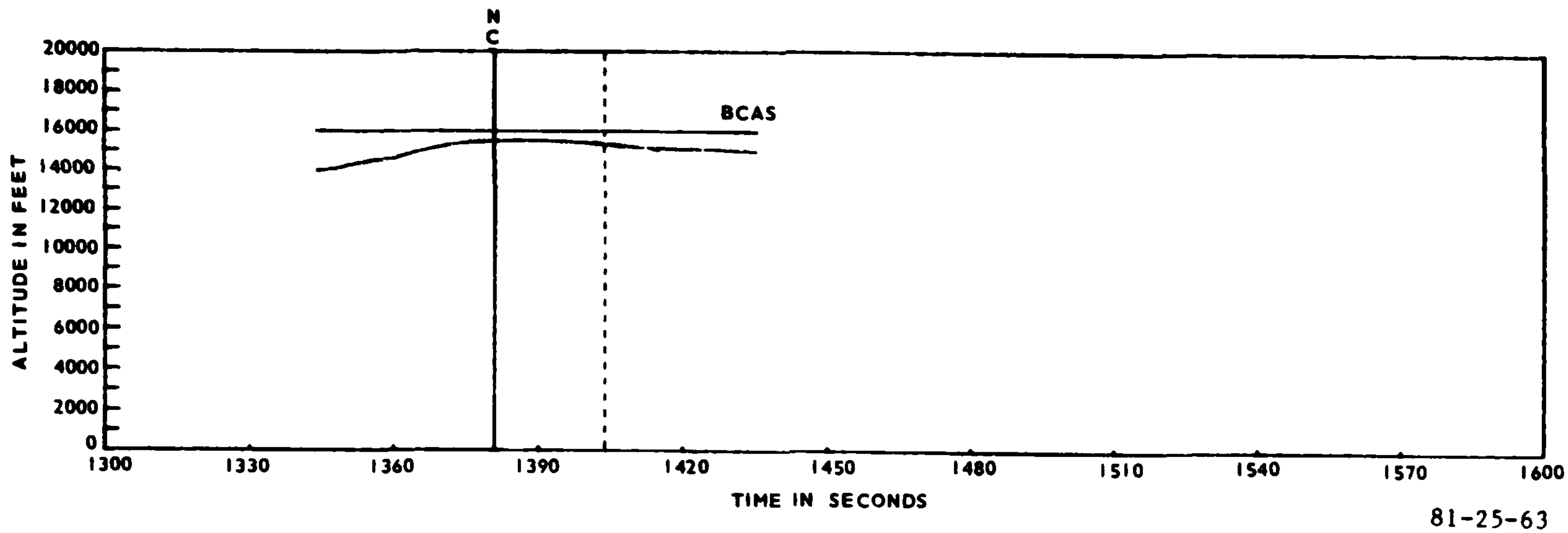


FIGURE 63. TARGET OF OPPORTUNITY (ALTITUDE, ENCOUNTER 1), CANTON, OHIO, AUGUST 4, 1980 (Y327)

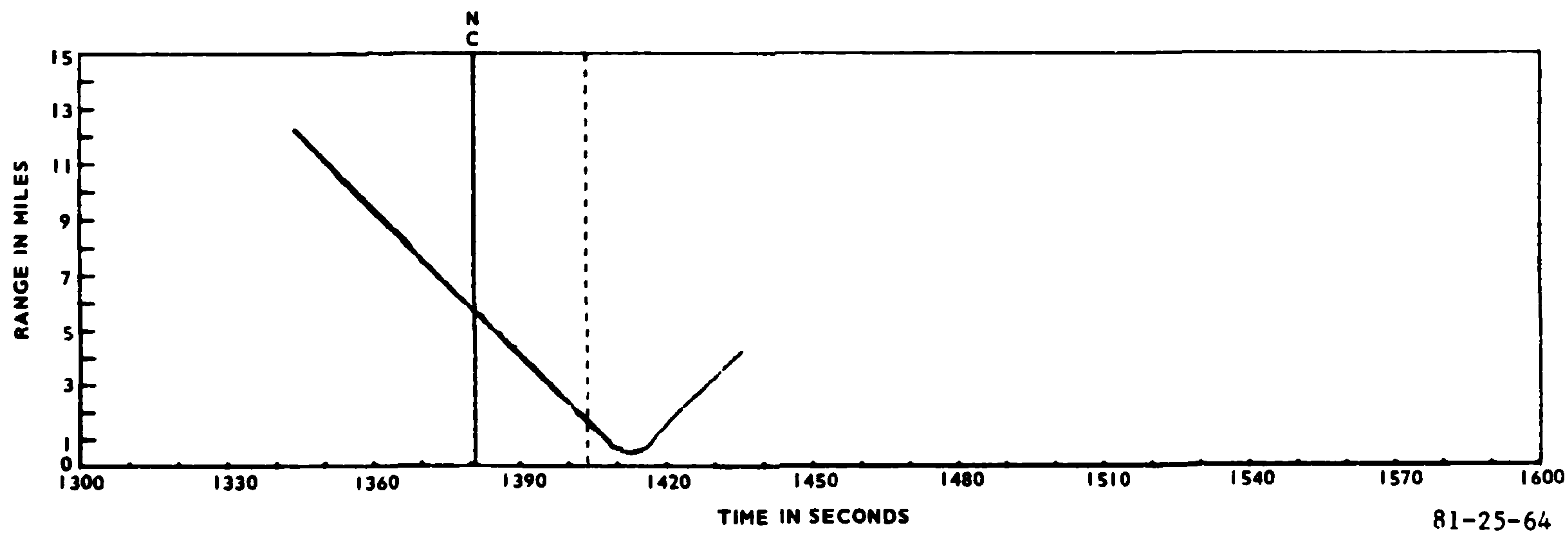
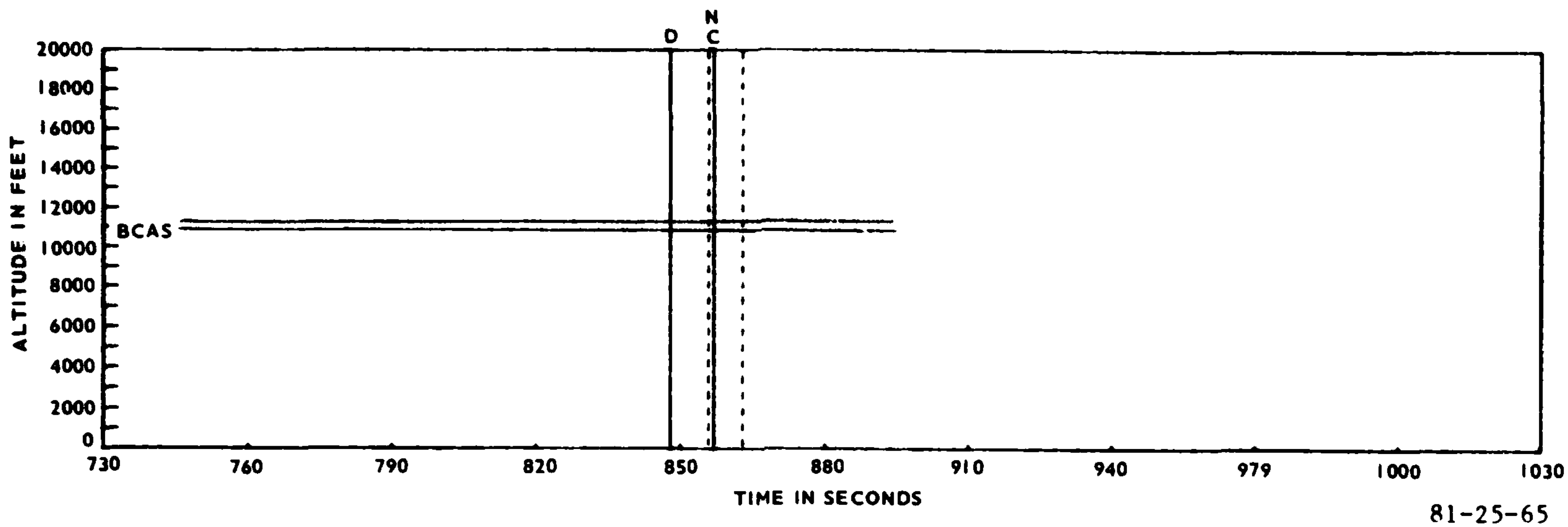
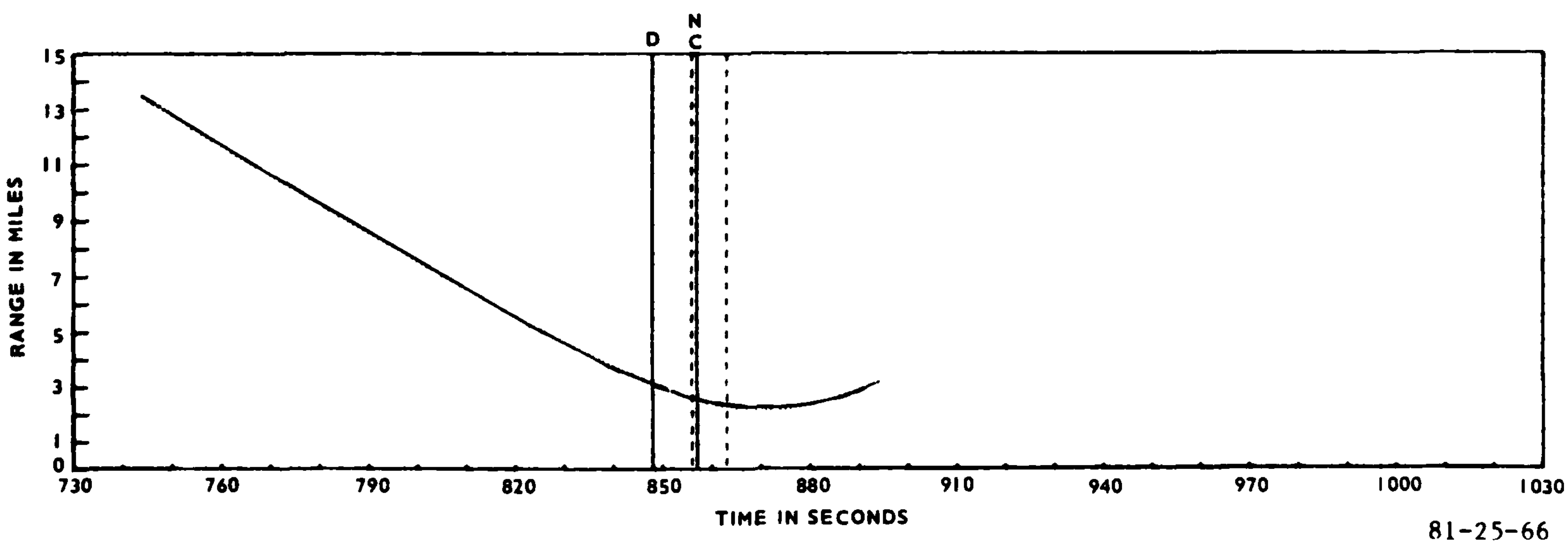


FIGURE 64. TARGET OF OPPORTUNITY (RANGE, ENCOUNTER 1), CANTON, OHIO, AUGUST 4, 1980 (Y327)



81-25-65

FIGURE 65. TARGET OF OPPORTUNITY (ALTITUDE, ENCOUNTER 2), CANTON, OHIO, AUGUST 8, 1980 (Y327)



81-25-66

FIGURE 66. TARGET OF OPPORTUNITY (RANGE, ENCOUNTER 2), CANTON, OHIO, AUGUST 8, 1980 (Y327)

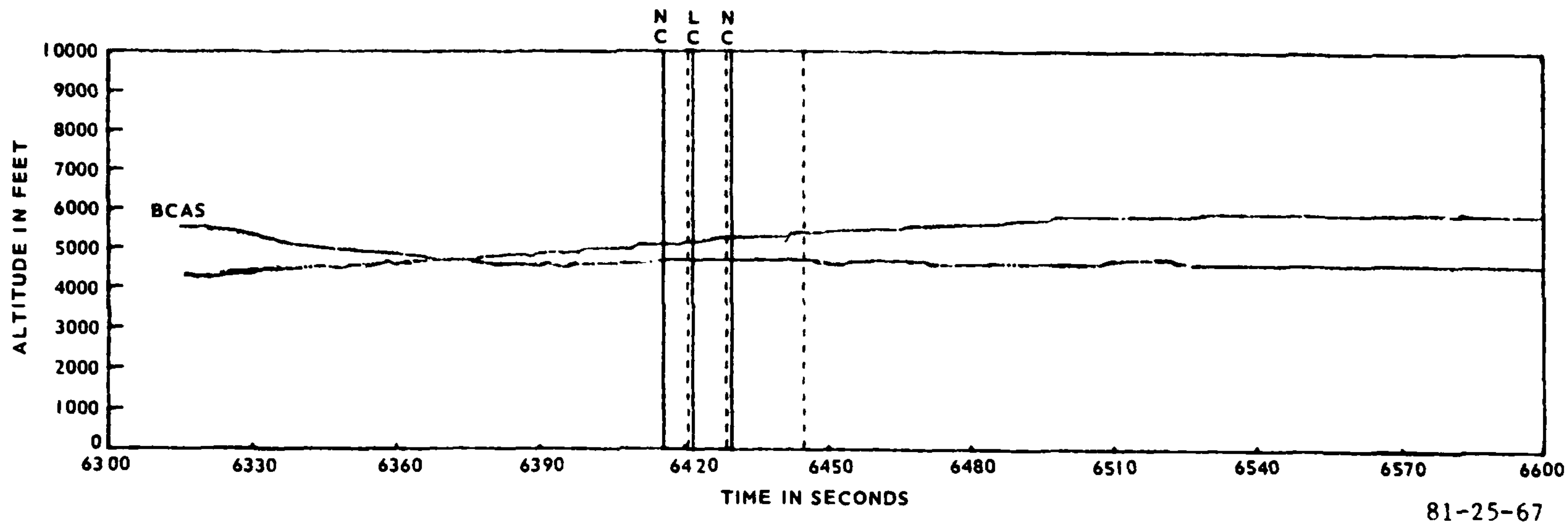


FIGURE 67. TARGET OF OPPORTUNITY (ALTITUDE), FAA TECHNICAL CENTER, OCTOBER 8, 1980 (C004)

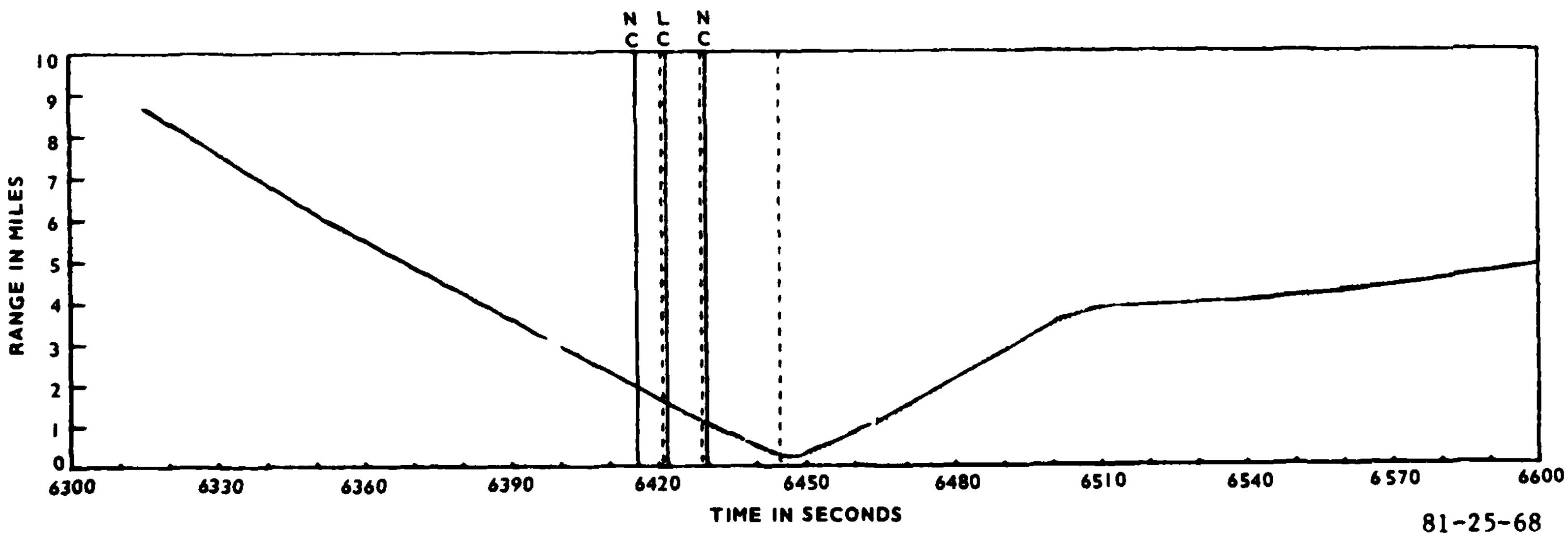


FIGURE 68. TARGET OF OPPORTUNITY (RANGE), FAA TECHNICAL CENTER, OCTOBER 8, 1980 (C004)

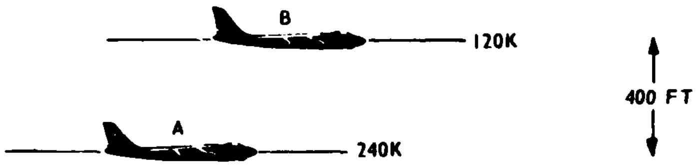
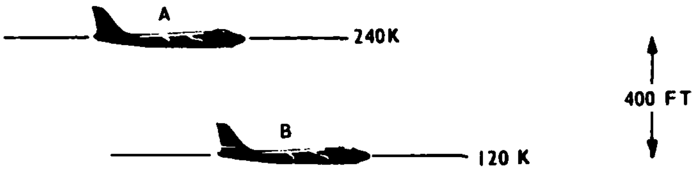
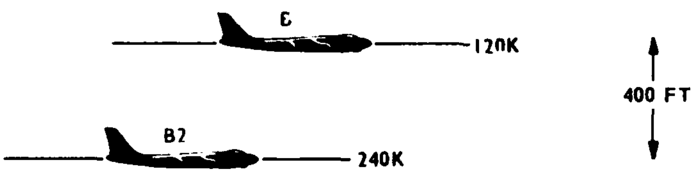
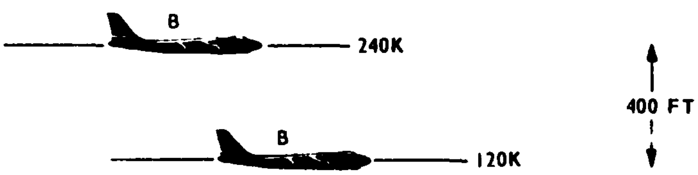
APPENDIX A

TEST PATTERNS

The total flight test program consisted of flying many other test patterns than those listed below and illustrated on the following pages. These listed patterns and flight areas are associated with this data report.

Run No.	Pattern	Description
1	1A	2 A/C tail-chase, BCAS ahead and above
3	1A	2 A/C tail-chase, BCAS ahead and below
11	2A	2 A/C head-on, BCAS above
12	2A	2 A/C head-on, BCAS above
13	2A	2 A/C head-on, BCAS below
14	2A	2 A/C head-on, BCAS below
10A	45°H	2 A/C, 45° horizontal tail closure
10B	45°H	2 A/C, 45° horizontal tail closure
15A	45°H	2 A/C, 45° horizontal head-on closure
15B	45°H	2 A/C, 45° horizontal head-on closure
90°		BCAS/target, 90° horizontal closure
21	3A	2 A/C, tail-chase, BCAS behind and above
47	4A	2 A/C, head-on, BCAS below
48	4A	2 A/C, head-on, BCAS above
49	4A	2 A/C, head-on, BCAS above
50	4A	2 A/C, head-on, BCAS below
135	8A	2 A/C, head-on, BCAS above
136	8A	2 A/C, head-on, BCAS above
137	8A	2 A/C, head-on, BCAS below
138	8A	2 A/C, head-on, BCAS below
157	9D	3 A/C, same headings, BCAS in middle descending
158	9D	3 A/C, same headings, BCAS in middle descending
159	9D	3 A/C, same headings, BCAS in middle climbing
160	9D	3 A/C, same headings, BCAS in middle climbing
177	10D	3 A/C, BCAS head-on and between descending on lower target
178	10D	3 A/C, BCAS head-on and between descending on lower target
179	10D	Like 177 except climbing into top target
180	10D	Like 177 except climbing into top target

PATTERN # 1

CONFIGURATION	REPLICATIONS	RUN #
A		
	2	1 2
	2	3 4
B		
	1	5
	1	6

B = BEU EQUIPPED
A = ATCRBS EQUIPPED

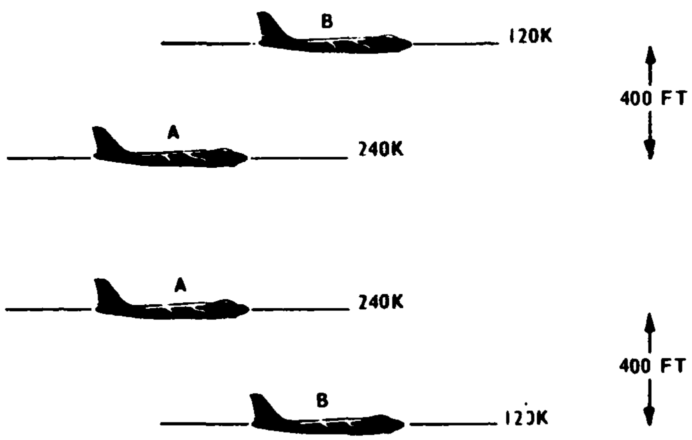
DATA RECORDED AND PROCESSED BY THE FAA TECHNICAL CENTER

PAGE NUMBER ____

PATTERN # 1

CONFIGURATION	REPLICATIONS	RUN #

C

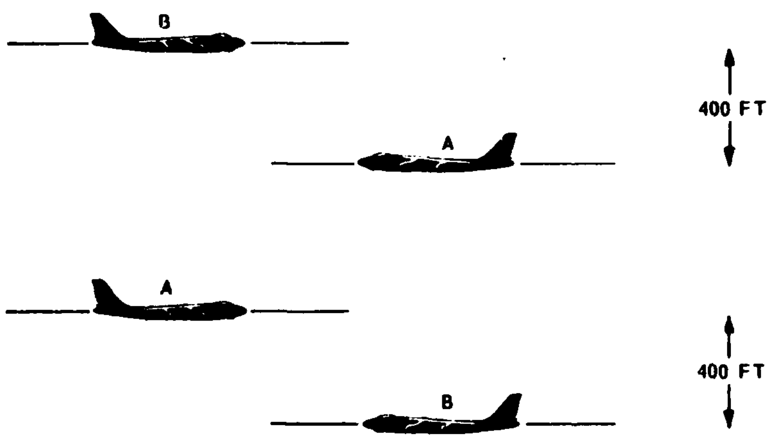


C (B 120K above A 240K, 400 FT)	2	7
		8
C (A 240K above B 120K, 400 FT)	2	9
		10

PATTERN # 2

A

EACH AIRCRAFT 165K



A (B above A, 400 FT)	2	11
		12
A (A above B, 400 FT)	2	13
		14

B = BEU EQUIPPED
A = ATCRBS EQUIPPED

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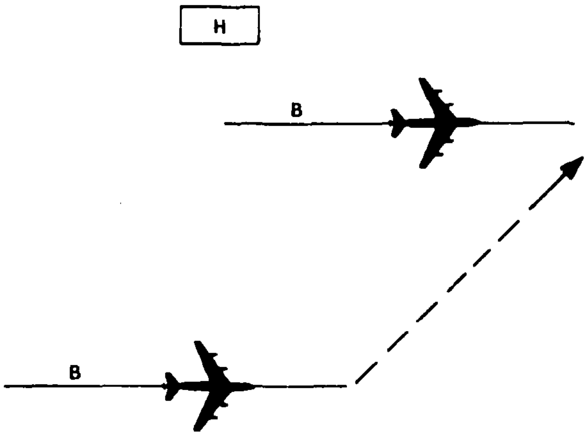
PAGE NUMBER ____

PATTERN # H 45°

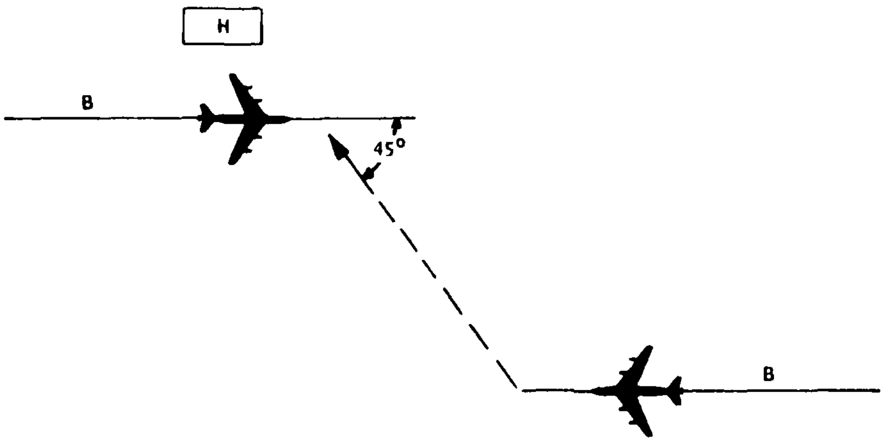
CONFIGURATION

REPLICATIONS RUN # ___



10A

10B



15A

15B

B = BEU EQUIPPED
A = ATCRBS EQUIPPED

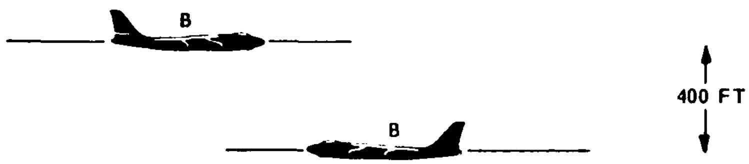
DATA RECORDED AND PROCESSED
BY THE FAA TECHNICAL CENTER

PAGE NUMBER ___

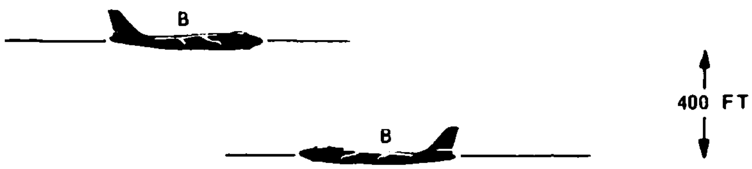
PATTERN # 2

CONFIGURATION	REPLICATIONS	RUN #

B EACH AIRCRAFT 165K

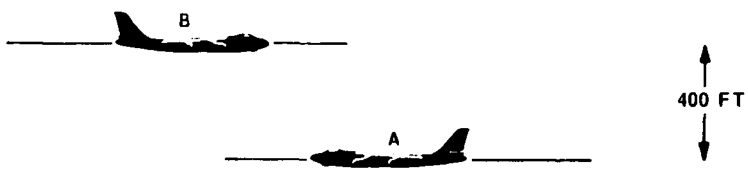


	1	15

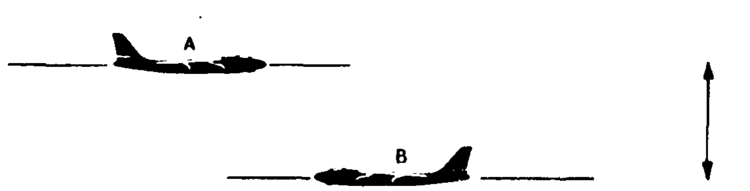


	1	16

C EACH AIRCRAFT 165K



	2	17
		18



	2	19
		20

B = BEU EQUIPPED
A = ATCRBS EQUIPPED

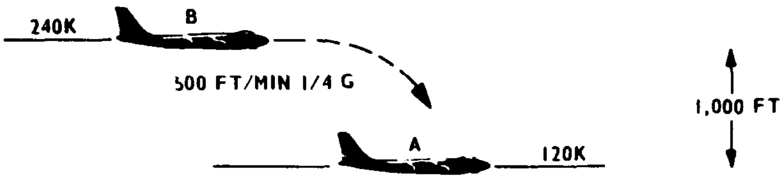
DATA RECORDED AND PROCESSED BY THE FAA TECHNICAL CENTER

PAGE NUMBER ____

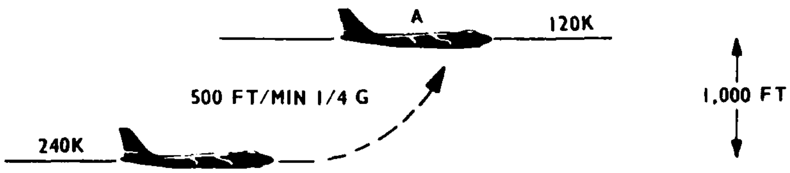
PATTERN # 3

CONFIGURATION	REPLICATIONS	RUN #

A

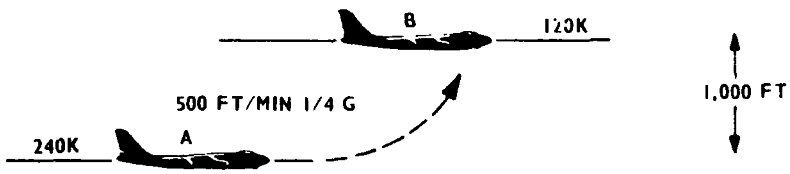


	2	21 22

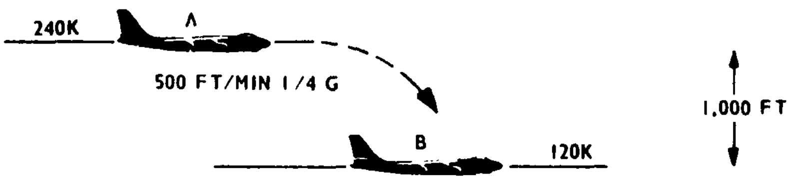


	2	23 24

A



	2	25 26



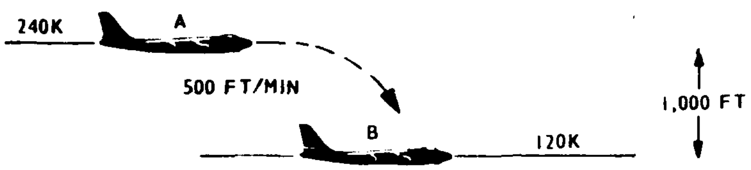
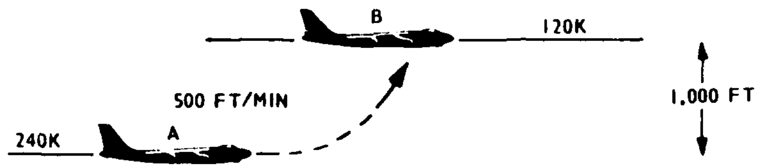
	2	27 28

B = BEU EQUIPPED
A = ATCRBS EQUIPPED

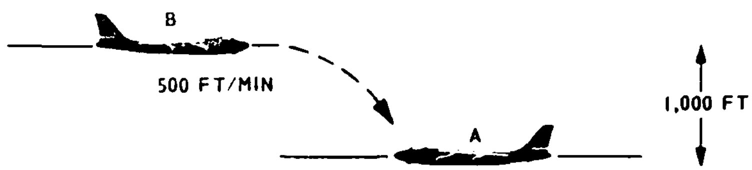
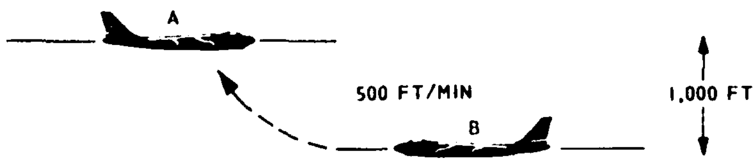
DATA RECORDED AND PROCESSED BY THE FAA TECHNICAL CENTER

PAGE NUMBER ____

PATTERN # 3

CONFIGURATION	REPLICATIONS	RUN #
C		
	2	43 44
	2	45 46

PATTERN # 4

CONFIGURATION	REPLICATIONS	RUN #
A — BOTH AIRCRAFT SAME SPEED		
	2	47 48
	2	49 50

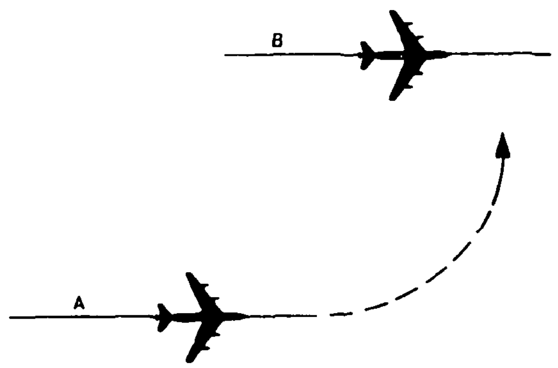
B = BEU EQUIPPED
A = ATCRBS EQUIPPED

DATA RECORDED AND PROCESSED BY THE FAA TECHNICAL CENTER

PAGE NUMBER ____

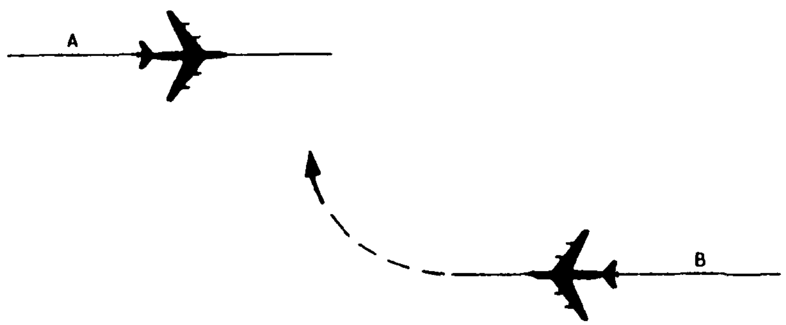
PATTERN # 7

CONFIGURATION	REPLICATIONS	RUN #
C	4	131 132 133 134



PATTERN # 8

CONFIGURATION	REPLICATIONS	RUN #
A	4	135 136 137 138

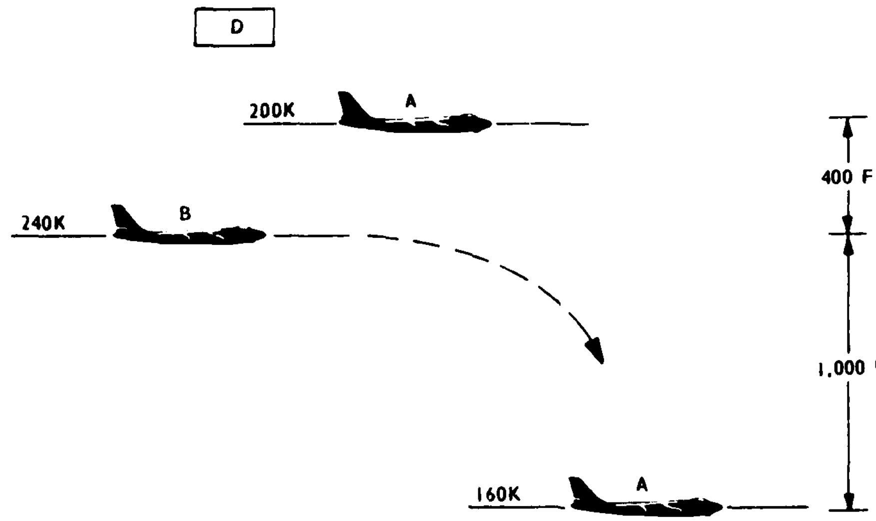
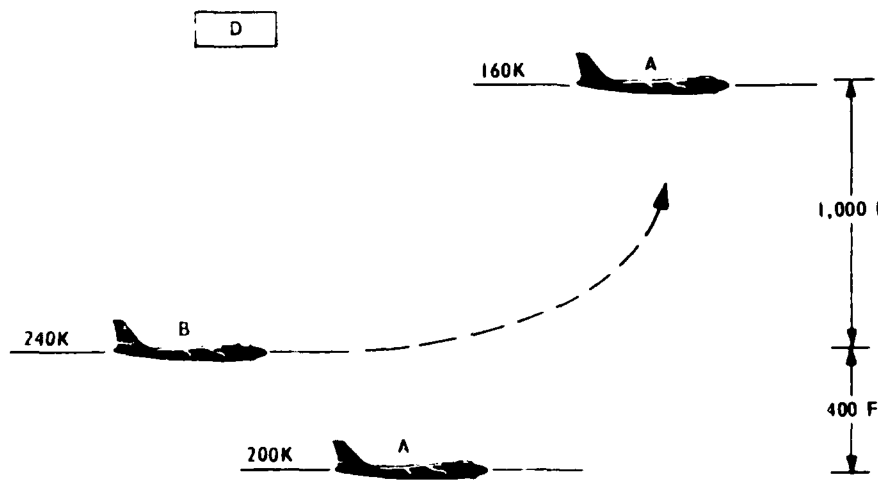


B = BEU EQUIPPED
A = ATCRBS EQUIPPED

DATA RECORDED AND PROCESSED
BY THE FAA TECHNICAL CENTER

PAGE NUMBER ____

PATTERN # 9

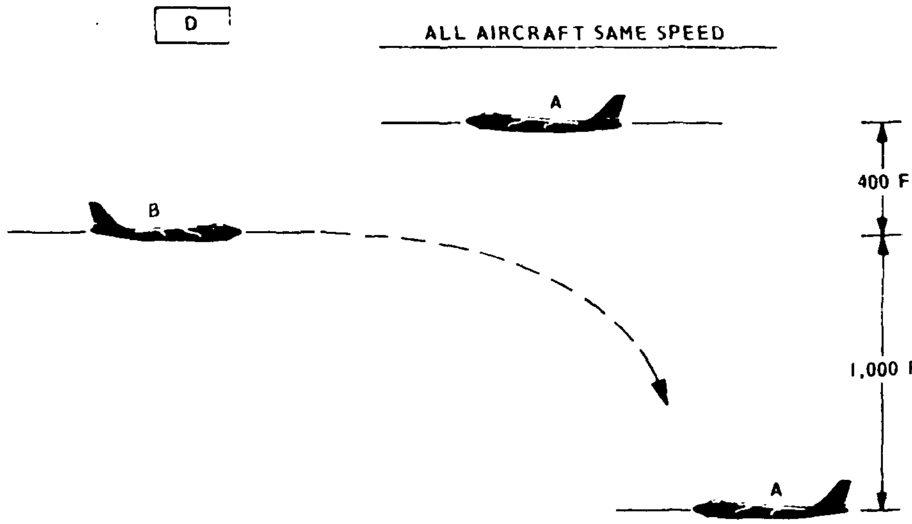
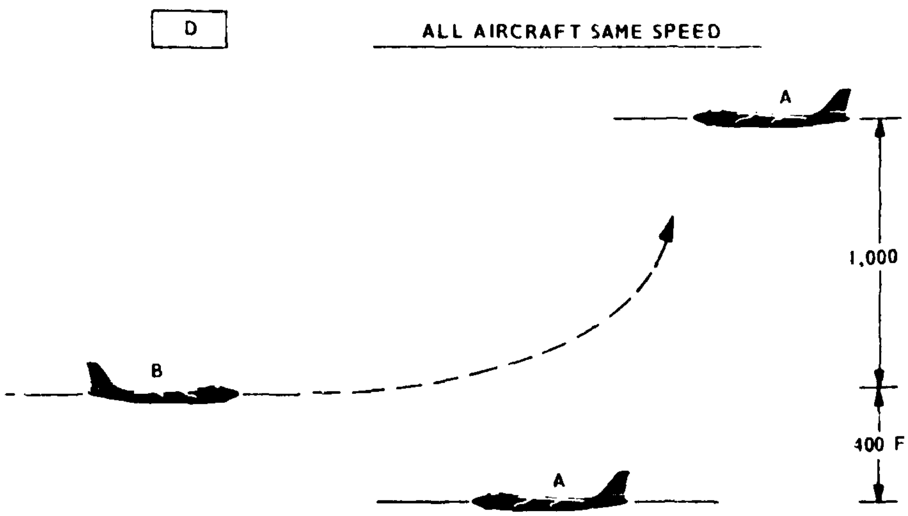
CONFIGURATION	REPLICATIONS	RUN #
	2	157 158
	2	159 160

B = BEU EQUIPPED
A = ATCRBS EQUIPPED

DATA RECORDED AND PROCESSED BY THE FAA TECHNICAL CENTER

PAGE NUMBER ____

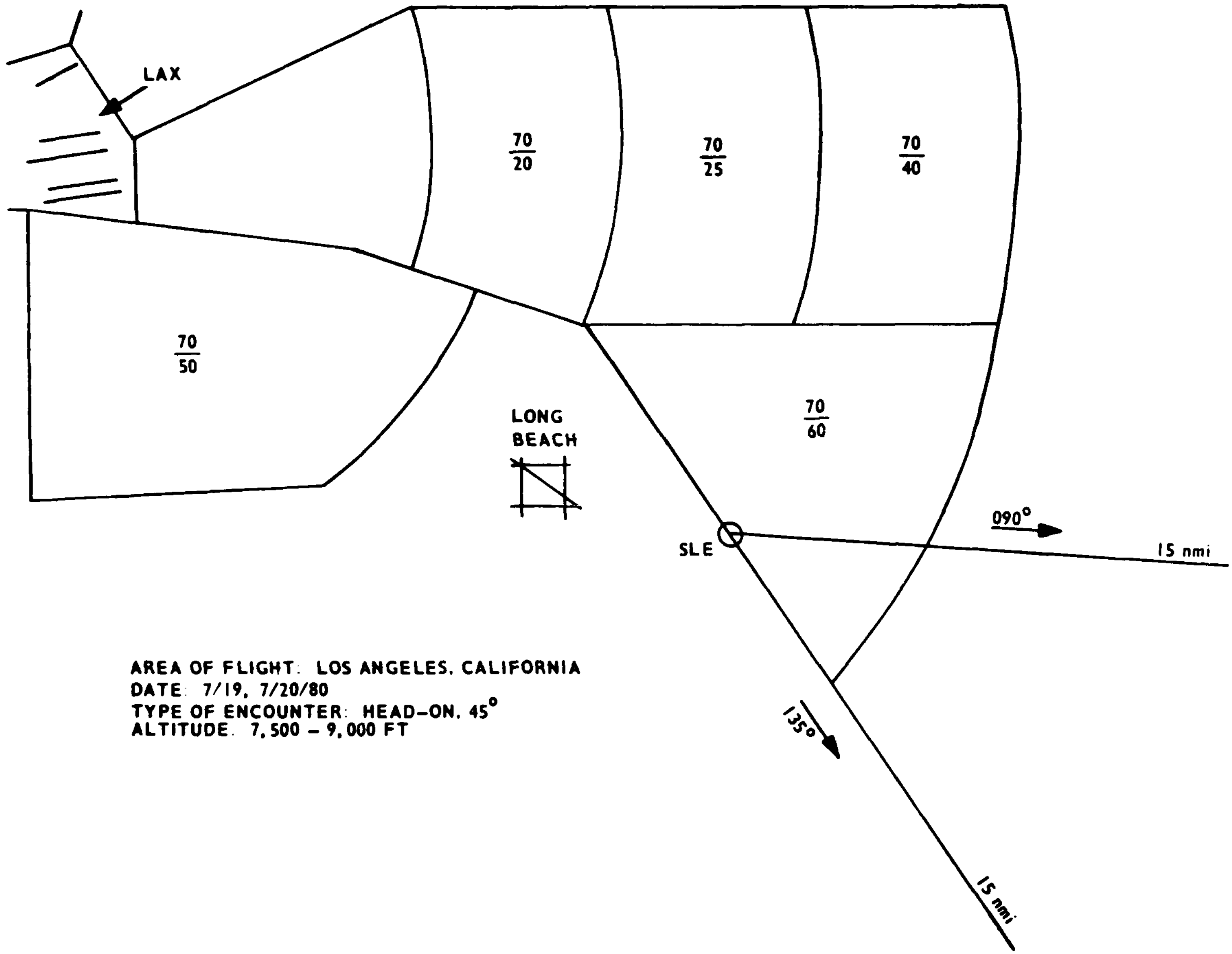
PATTERN # 10

CONFIGURATION	REPLICATIONS	RUN #
	2	177 178
	2	179 180

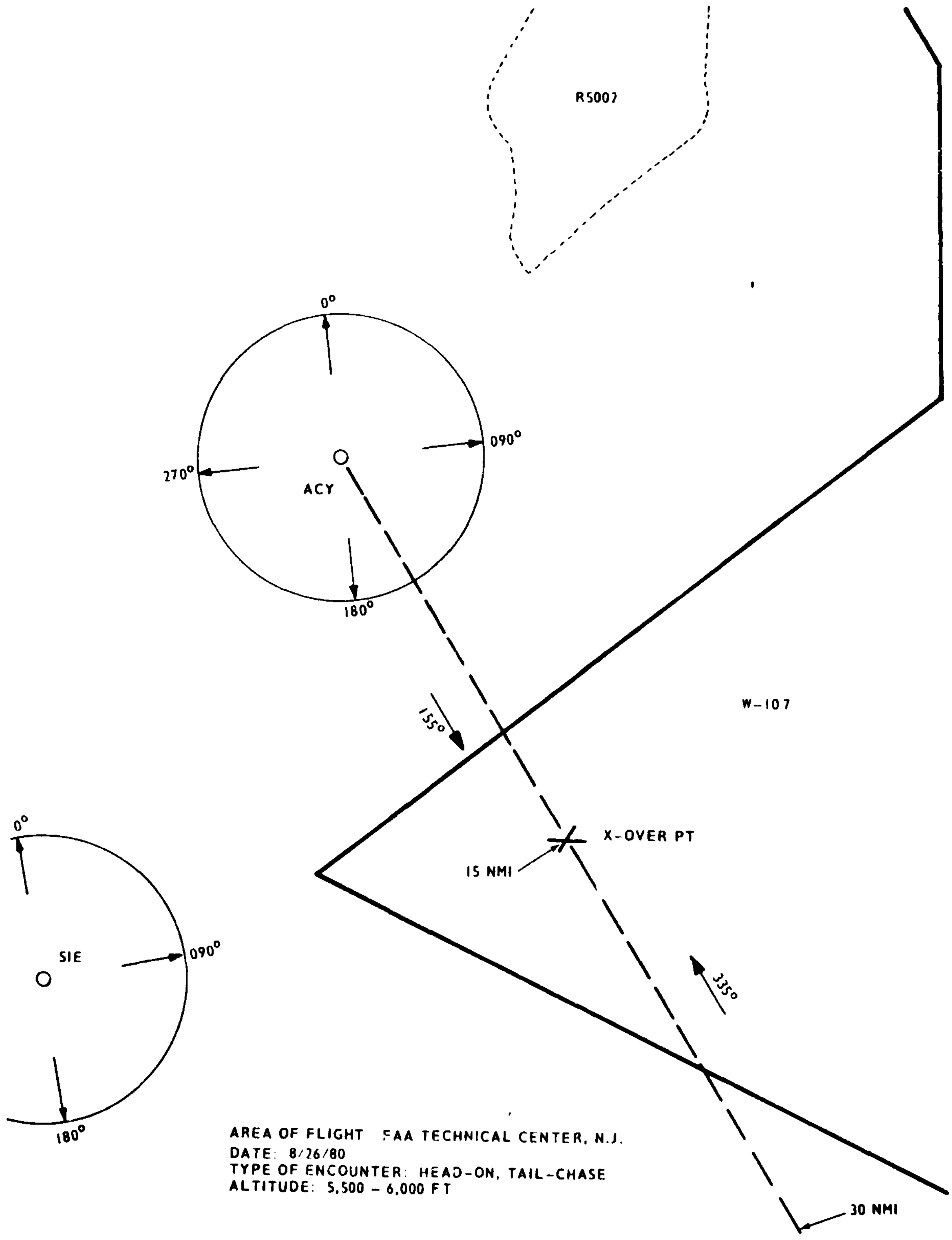
B = BEU EQUIPPED
A = ATCRBS EQUIPPED

DATA RECORDED AND PROCESSED
BY THE FAA TECHNICAL CENTER

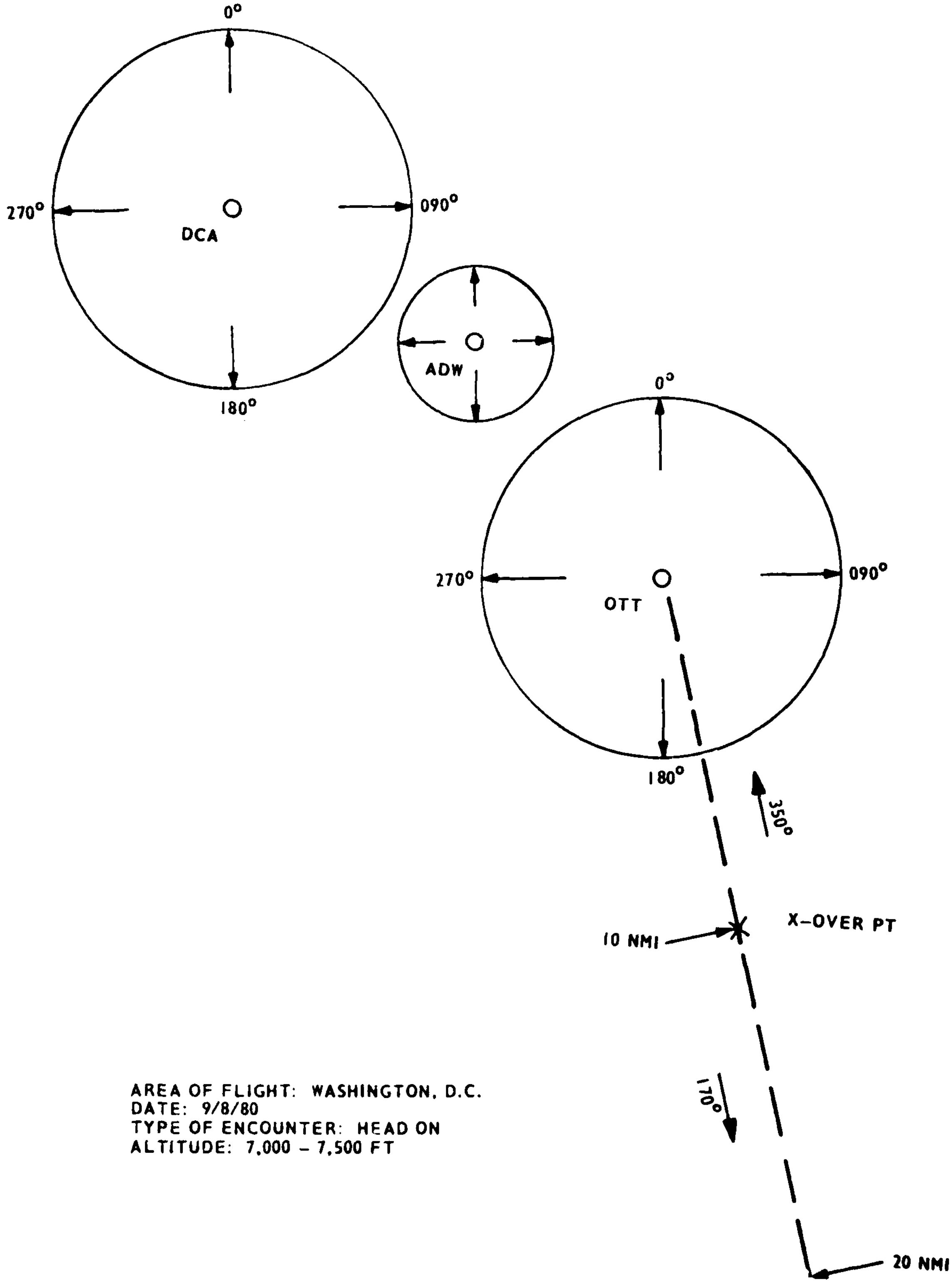
PAGE NUMBER ___



AREA OF FLIGHT: LOS ANGELES, CALIFORNIA
DATE: 7/19, 7/20/80
TYPE OF ENCOUNTER: HEAD-ON, 45°
ALTITUDE: 7,500 – 9,000 FT

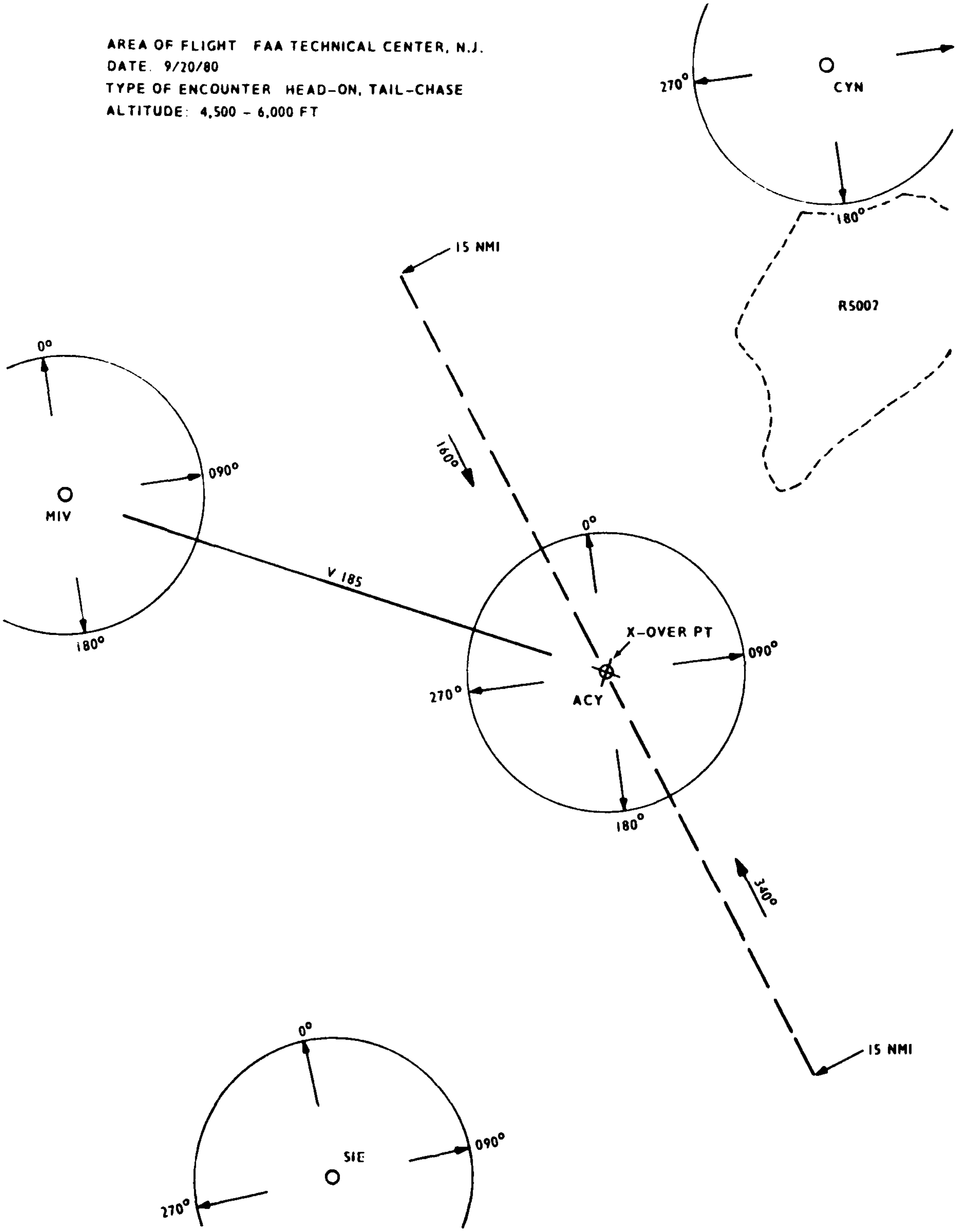


AREA OF FLIGHT FAA TECHNICAL CENTER, N.J.
DATE: 8/26/80
TYPE OF ENCOUNTER: HEAD-ON, TAIL-CHASE
ALTITUDE: 5,500 – 6,000 FT



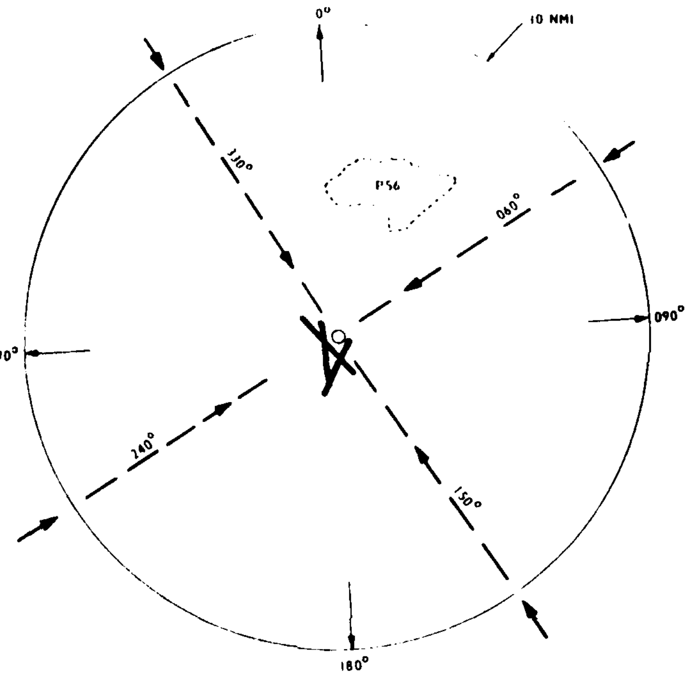
AREA OF FLIGHT: WASHINGTON, D.C.
DATE: 9/8/80
TYPE OF ENCOUNTER: HEAD ON
ALTITUDE: 7,000 – 7,500 FT

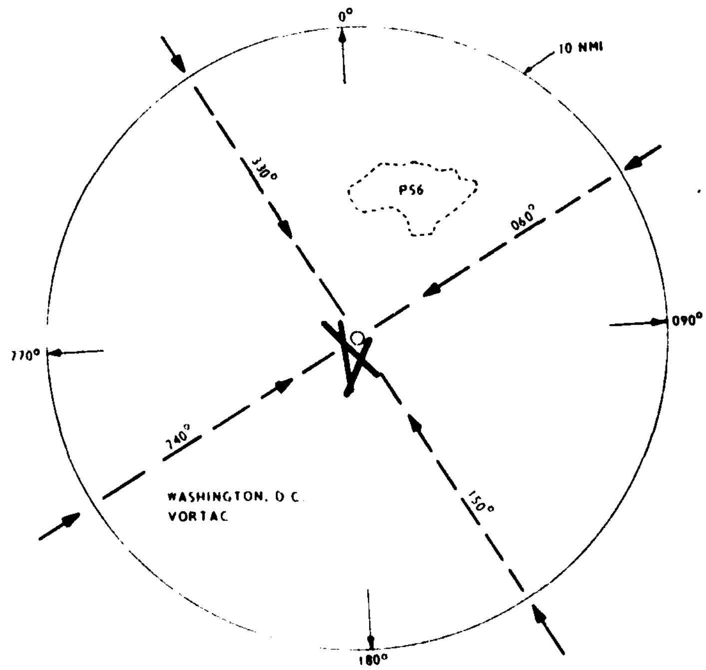
AREA OF FLIGHT   FAA TECHNICAL CENTER, N.J.
DATE: 9/20/80
TYPE OF ENCOUNTER   HEAD-ON, TAIL-CHASE
ALTITUDE: 4,500 - 6,000 FT



AREA OF FLIGHT WASHINGTON, D.C.
TYPE OF ENCOUNTER HEAD ON, 090° RADIALS
HEAD ON 090° 270°
NINETY DEGREES 060° 330°, 240° 150°
090° 180°, 270° 180°
ALTITUDE 6,5000 7,500 FT

DATE 6 28 80





APPENDIX B

MESSAGE RECORDS

BCAS/BEU MESSAGE TYPE 1

This message records the own-aircraft status table at the beginning of each 1-second scan.

Column		Meaning
1	SYS TIME	System time in seconds.
2	ALT	Altitude as read from own aircraft's altimeter in feet of own aircraft.
3	TRACKED ALT	Tracked altitude of own aircraft from altitude tracker in feet.
4	ADOT	Altitude rate of own aircraft in ft/sec.
5	CSL	Current sensitivity level.
6	LSL	Last sensitivity level.
7	AT SYSTIM	System time at which the ATC sensitivity level was received.
8	RBX	RBX in track flag.
9	RBX RANGE	Range to nearest RBX in track.
10	OUTER LIMIT	Outer range limit specified by nearest RBX in track.
11	INNER LIMIT	Inner range limit specified by nearest RBX in track.
12	NEXT SCAN	System time when next scan will begin in seconds.
13	THIS SCAN	System time when this scan began in seconds.
14	CUR IDL CT	Current idle count counter is incremented by system idle loop whenever no other processing needs to be done.
15	LAST IDL	The last second's idle count sample. The fraction of time the CPU was idle during that second.
16	MIN IDL	Minimum of idle count samples since system initialization.
17	DABS ID	Own aircraft's DABS identity code.
18	TAPE STATUS 15-11.	

Bit 15: current tape drive
0 = drive 1, 1 = drive 2

Bit 14-13: current track
00 = track 1, 01 = track 2
10 = track 3, 11 = track 4

Bit 11: drive type assumed by software
0 = single, 1 = dual

19 RADAR STATUS - Radar altimeter status.

Bit is: 0 = not using radar altimeter
= using radar altimeter

Bit 0: 0 = below threshold, 1 = above threshold

20 REC NO. - BCAS conversion software record number.

BCAS/BEU MESSAGE TYPE 3.

This message records data for each ATCRBS interrogation and is followed immediately by message 4 which records the replies from the interrogation.

SYS TIME - BEU system time in seconds.

LIST INTVL - Receiver listening interval in nanoseconds.

MTL CNTRL - Minimum threshold level control in dB.

INIT STC - Initial sensitivity time control level at 1 nautical mile in dB.

STC - Sensitivity time control circuit, 0 = OFF, 1 = ON, ignored for DABS and squitter modes, when STC is always off.

DM - Dynamic MTL control, 0 = disabled, 1 = enabled.

PB - Phantom rejection control of ATCRBS reply processor. 0 = accepts all replies, 1 = rejects all phantoms.

PC INTRR - Power control interrogation, transmitter power attenuator control for interrogation in 1 dB steps where 0 = 31 dB alteration, 31 = 0 dB attenuation.

PC SUP - Power control suppression, transmitter power attenuator control for P1 - P2 suppression pair in 1 dB steps. 0 = 31 dB attenuation, 31 = 0 dB attenuation.

MCU Mode - Modulator control unit mode select, 0101 = mode C, no P4, no suppression, 0111 = mode C, no P4, suppression.

MCU Mode - Modulator control unit mode select, 0101 = mode C, no P4, no suppression, 0111 = mode C, no P4, suppression.

D - Diversity switch control, 0 = top antenna, 1 = bottom antenna.

STATUS - Status of the reply buffer, 0 = empty, 2 = full.

LENGTH - The number of replies received from this interrogation.

BCAS/BEU MESSAGE TYPE 4

This message records the ATCRBS replies received from the interrogation which precedes it (message 3).

SYS TIME - BEU system time in seconds.

OBIT - Buffer overflow bit. It is set ("1") when the buffer is full (contains four replies) and a decoder has a reply ready to be transferred to the buffer. This latter reply will be ignored. The 0 bit is reset when the condition is reported to the CPU via the subsequent reply.

IBIT - Insufficient decoders bit. This bit is set ("1") if a bracket is detected during a period when all four decoders are busy. It is reset when the condition is reported to the CPU via the first of the four replies-in-process that is transferred to the CPU.

PBIT - Phantom bit. It is set ("1") when this reply is a potential phantom — that is a bracket pair whose F1 pulse occurs in one of the 14 intervals (N*12) ±1 (N-1, 2...14) after the F1 pulse leading edge sample of a previously declared bracket pair.

FLIGHT LEVEL - Intruders altitude, mode C code in feet.

GD1, GD2,...GC4 - Garble bit for each ATCRBS data bit. Each bit is set ("1") when the corresponding leading edge sample of a code pulse occurs in one of the leading edge sample positions (N*12) ±2 (N=1, 2,... 15) of code pulses of another reply being decoded.

MODE - Mode of reply.

RANGE - Calculated range to intruder in nmi.

BCAS/BEU MESSAGE TYPE 10

This message records the CAS intruder track file once per 1-second scan after all updates to the file have been made.

Column	MEANING
1	SYS TIME - BEU system time in seconds.
2	TR RNG - Intruder tracked range in nmi.

3 TR RDOT - Intruder tracked range rate in nmi/sec, negative indicates closing.

4 TR ALT - Intruder tracked altitude in feet.

5 TR ADOT - Intruder tracked altitude rate, negative indicates intruder's altitude is decreasing, in ft/sec.

6 UPDATE - Time of the latest CAS track file update in seconds.

7 REPORT - Time of latest report used to update the CAS track file in seconds.

8 ACTION - Time intruder command selected.

9 INTENT - Own aircraft maneuver intent.

10 LAST INTENT - Previous command or advisory.

11 VSL - Vertical speed limit.

12 HITS - CAS logic hit counter.

13 CPL - CAS performance level.

14 TYPE - Bit 0: Drop flag, 1 = delete command.
Bit 1: Don't care flag, 1 = don't care.
Bit 2: Equipage, 1 = equipped with BCAS.
Bit 4: ATCRBS/DABS target, 1 = DABS.

15 DABSID - ATCRBS or DABS identification.
ATCRBS = internal track identifier.
DABS = intruders DABS identification code.

BCAS DATA SET - TAPE [illegible] 00000360

BCAS MESSAGE TYPE 1

SYS TIME	TRACKED ALT	ALT	ADOT	ISL	LSL	Z AT SYSTEM	RBX FLAG	RBX RNG	OUTER LIMIT	INNER LIMIT	NEXT SCAN	THIS SCAN	CUR IDL CT	LAST IDL	MIN IDL	DABS ID	TAPE STATUS 15-11	RADAR STATUS 15-14	REC#
5883	5400	5323	-2	4	0	0	0	0.	0.	0.	5884	5883	1	0.779	528	1057	00101	1 0	3703
5884	5400	5323	-1	4		0	0	0.	0.	0.	5885	5884	1	0.671	528	1057	00101	1 0	3703
5885	5400	5323	-1	4	0	0	0	0.	0.	0.	5886	5885	1	0.675	528	1057	00101	1 0	3704
5886	5400	5314	-1	4	0	0	0	0.	0.	0.	5887	5886	1	0.773	528	1057	00101	1 0	3704
5887	5400	5323	0	4	0	0	0	0.	0.	0.	5888	5887	1	0.677	528	1057	00101	1 0	3705
5888	5400	5323	0	4	0	0	0	0.	0.	0.	5889	5888	1	0.778	528	1057	00101	1 0	3705
5889	5400	5323	1	4	0	0	0	0.	0.	0.	5890	5889	1	0.667	528	1057	00101	1 0	3706
5890	5300	5354	-4	4	0	0	0	0.	0.	0.	5891	5890	1	0.773	528	1057	00101	1 0	3706
5891	5300	5331	-7	4	0	0	0	0.	0.	0.	5892	5891	1	0.670	528	1057	00101	1 0	3707
5892	5300	5312	-8	4	0	0	0	0.	0.	0.	5893	5892	1	0.767	528	1057	00101	1 0	3707
5893	5300	5300	-8	4	0	0	0	0.	0.	0.	5894	5893	1	0.672	528	1057	00101	1 0	3708
5894	5300	5295	-8	4	0	0	0	0.	0.	0.	5895	5894	1	0.774	528	1057	00101	1 0	3709
5895	5200	5250	-10	4	0	0	0	0.	0.	0.	5896	5895	1	0.677	528	1057	00101	1 0	3709
5896	5200	5225	-14	4		0	0	0.	0.	0.	5897	5896	1	0.672	528	1057	00101	1 0	3710
5897	5200	5204	-15	4	0	0	0	0.	0.	0.	5898	5897	1	0.773	528	1057	00101	1 0	3710
5898	5200	5174	-14	4	0	0	0	0.	0.	0.	5899	5898	1	0.669	528	1057	00101	1 0	3711
5899	5200	5187	-11	4	0		0	0.	0.	0.	5900	5899	1	0.778	528	1057	00101	1 0	3711
5900	5200	5181	-10	4	0	0	0	0.	0.	0.	5901	5900	1	0.675	528	1057	00101	1 0	3712
5901	5200	5181	-1[illegible]	4	0	0	0	0.	0.	0.	5902	5901	1	0.774	528	1057	00101	1 0	3712
5902	5200	5181	[illegible]	4	0	0	0	0.	0.	0.	5903	5902	1	0.666	528	1057	00101	1 0	3713
5903	5200	5181	-7	4	0	0	0	0.	0.	0.	5904	5903	1	0.766	528	1057	00101	1 0	3713
5904	5200	5183	-5	4	0	0	0	0.	0.	0.	5905	5904	1	0.674	528	1057	00101	1 0	3714
5905	5200	5187	-7	4	0	0	0	0.	0.	0.	5906	5905	1	0.775	528	1057	00101	1 0	3714
5906	5200	5187	[illegible]	4		0	0	0.	0.	0.	5907	5906	1	0.673	528	1057	00101	1 0	3715
5907	5200	5147	-7	4		0	0	0.	0.	0.	5908	5907	1	0.672	528	1057	00101	1 0	3716
5908	5200	5147	-2	4		0	0	0.	0.	0.	5909	5908	1	0.772	528	1057	00101	1 0	3716
5909	5200	5147	-1	4	0	0	0	0.	0.	0.	5910	5909	1	0.671	528	1057	00101	1 0	3717
5910	5200	5148	-1	4		0	0	0.	0.	0.	5911	5910	1	0.768	528	1057	00101	1 0	3717
5911	5200	5127		4	0	0	0	0.	0.	0.	5912	5911	1	0.666	528	1057	00101	1 0	3718
5912	5200	5123		4		0	0	0.	0.	0.	5913	5912	1	0.767	528	1057	00101	1 0	3718
5913	5200	5128	[illegible]	4		0	0	0.	0.	0.	5914	5913	1	0.669	528	1057	00101	1 0	3719
5914	5200	5123	[illegible]	4	0	0	0	0.	0.	0.	5915	5914	1	0.666	528	1057	00101	1 0	3720
5915	5200	514[illegible]	[illegible]	4	0	0	0	0.	0.	0.	5916	5915	1	0.761	528	1057	00101	1 0	3720
5916	5100	5154	-4	4	0	0	0	0.	0.	0.	5917	5916	1	0.668	528	1057	00101	1 0	3721
5917	5100	5151	-4	4		0	0	0.	0.	0.	5918	5917	1	0.769	528	1057	00101	1 0	3721
5918	5100	5117	-7	4	0	0	0	0.	0.	0.	5919	5918	1	0.673	528	1057	00101	1 0	3722
5919	5100	5130	-8	4	0	0	0	0.	0.	0.	5920	5919	1	0.676	528	1057	00101	1 0	3723
5920	5100	5127	-7	4	0	0	0	0.	0.	0.	5921	5920	1	0.772	528	1057	00101	1 0	3723
5921	5100	5127	-7	4	0	0	0	0.	0.	0.	5922	5921	1	0.676	528	1057	00101	1 0	3724
5922	5100	5131	-1	4	0	0	0	0.	0.	0.	5923	5922	1	0.772	528	1057	00101	1 0	3724
5923	5100	5156	2	4	0	0	0	0.	0.	0.	5924	5923	1	0.672	528	1057	00101	1 0	3725
5924	5100	5175	4	4	0	0	0	0.	0.	0.	5925	5924	1	0.757	528	1057	00101	1 0	3725
5925	5200	5187	5	4	0	0	0	0.	0.	0.	5926	5925	1	0.670	528	1057	00101	1 0	3726
5926	5200	5195	5	4	0	0	0	0.	0.	0.	5927	5926	1	0.673	528	1057	00101	1 0	3727
5927	5200	5233	5	4	0	0	0	0.	0.	0.	5928	5927	1	0.771	528	1057	00101	1 0	3727
5928	5300	5245	10	4	0	0	0	0.	0.	0.	5929	5928	1	0.669	528	1057	00101	1 0	3728
5929	5300	5275	12	4	0	0	0	0.	0.	0.	5930	5929	1	0.756	528	1057	00101	1 0	3728
5930	5300	5295	13	4	0	0	0	0.	0.	0.	5931	5930	1	0.675	528	1057	00101	1 0	3729
5931	5300	5306	12	4	0	0	0	0.	0.	0.	5932	5931	1	0.770	528	1057	00101	1 0	3729
5932	5300	5312	11	4	0	0	0	0.	0.	0.	5933	5932	1	0.670	528	1057	00101	1 0	3730

81-25-B-1

FIGURE B-1. BCAS MESSAGE TYPE 1

AD-A121 246 PRELIMINARY EVALUATION OF THE BASIC EXPERIMENTAL ACTIVE BEACON COLLISION..(U) FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER ATLANTIC CIT.. E QUISH ET AL. MAR 82 2/2

UNCLASSIFIED DOT/FAA/CT-82-100-39LR DOT/FAA/RD-82/67 F/G 17/7 NL

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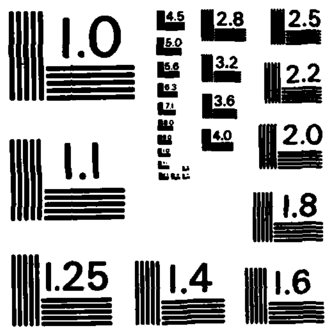

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 3

SYS TIME	LIST INTVL	MTL CNTRL	INIT STC	STC	DM	PB	P C INTRR	P C SUP	MCU MODE	D	STATUS	LENGTH
2352	-275000 NS	-77 DB	-77 DB	0	1	1	18 DB	31 DB	0101	1	0	0

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 3

SYS TIME	LIST INTVL	MTL CNTRL	INIT STC	STC	DM	PB	P C INTRR	P C SUP	MCU MODE	D	STATUS	LENGTH
2352	-275000 NS	-77 DB	-77 DB	0	1	1	12 DB	21 DB	0111	1	2	3

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 4

SYS TIME	O BIT	I BIT	P BIT	FLIGHT LEVEL	GD1	GD2	GD4	GA1	GA2	GA4	GB1	GB2	GB4	GC1	GC2	GC4	MODE	RANGE
2352	0	0	0	53000 FT	0	0	1	0	0	0	0	0	0	0	0	0	C	4.43 NM
2352	0	0	1	58300 FT	0	0	0	0	0	0	0	0	0	1	0	0	C	5.96 NM
2352	0	0	0	20600 FT	0	0	0	0	0	0	0	0	0	0	0	0	C	14.26 NM

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 3

SYS TIME	LIST INTVL	MTL CNTRL	INIT STC	STC	DM	PB	P C INTRR	P C SUP	MCU MODE	D	STATUS	LENGTH
2352	-275000 NS	-77 DB	-77 DB	0	1	1	6 DB	15 DB	0111	1	2	6

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 4

SYS TIME	O BIT	I BIT	P BIT	FLIGHT LEVEL	GD1	GD2	GD4	GA1	GA2	GA4	GB1	GB2	GB4	GC1	GC2	GC4	MODE	RANGE
2352	0	0	0	5300 FT	0	0	0	0	0	0	0	0	0	0	0	0	C	6.76 NM
2352	0	1	0	6200 FT	1	1	1	1	1	1	1	1	1	0	1	1	C	11.50 NM
2352	0	0	0	113200 FT	1	1	1	1	1	1	1	1	1	1	1	1	C	11.64 NM
2352	0	0	0	0 FT	0	0	0	0	0	0	0	0	0	0	0	0	A	11.93 NM
2352	0	0	0	-300 FT	1	1	1	0	0	0	0	1	1	1	1	1	C	12.49 NM
2352	0	0	0	19400 FT	0	0	0	1	0	0	0	0	0	1	1	0	C	13.79 NM

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 3

SYS TIME	LIST INTVL	MTL CNTRL	INIT STC	STC	DM	PB	P C INTRR	P C SUP	MCU MODE	D	STATUS	LENGTH
2352	-275000 NS	-77 DB	-77 DB	0	1	1	0 DB	9 DB	0111	1	2	4

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 4

SYS TIME	O BIT	I BIT	P BIT	FLIGHT LEVEL	GD1	GD2	GD4	GA1	GA2	GA4	GB1	GB2	GB4	GC1	GC2	GC4	MODE	RANGE
2352	0	0	0	54200 FT	1	1	1	0	1	1	1	1	1	0	0	1	C	11.50 NM
2352	0	0	0	7600 FT	0	0	0	0	0	0	0	0	0	0	0	0	C	12.48 NM
2352	0	0	1	4800 FT	0	0	0	0	0	0	0	0	0	1	0	0	C	13.02 NM
2352	0	0	0	3500 FT	0	0	0	0	0	0	0	0	0	0	0	0	C	15.21 NM

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 3

SYS TIME	LIST INTVL	MTL CNTRL	INIT STC	STC	DM	PB	P C INTRR	P C SUP	MCU MODE	D	STATUS	LENGTH
2352	-275000 NS	-77 DB	-77 DB	0	1	1	18 DB	31 DB	0101	0	0	0

BCAS DATA SET -LAX,N40- 07-20-80 TAPE D-479 ; S-5788 00000310 BCAS MESSAGE TYPE 3

81-25-B-2

FIGURE B-2. BCAS MESSAGE TYPES 3 AND 4

BCAS DATA SET - TAPE C-195,,S-1988?

SYSTEM	TR RNG	TR RDOT	TR ALT	TR ADOT	UPDATE	REPORT	ACTION	0000036C INTENT	LAST INTENT 10 <- 1	VSL	HITS	CPL	TYPE	DABS ID
5886	13.50	-12.[illegible]	3333	3	643.12	638.12	635.18	0000000000	0000000000	0	0	0	0000	00015707
5887	1.43	-351.[illegible]	6[illegible]	0	644.12	644.12	639.17	0001001000	0001001000	0	3	0	0000	00015610
5887	3.03	45.42	16712	-21	644.12	644.12	639.17	0000000000	0000000000	0	0	0	0000	00016033
5887	3.57	47.52	7506	0	644.12	644.12	639.17	0000000000	0000000000	0	0	0	0000	00016105
5887	9.24	-272.36	1912	5	644.12	643.12	639.17	0000000000	0000000000	0	0	0	0000	00015464
5887	11.33	-54.73	8300	0	644.12	644.12	639.18	0000000000	0000000000	0	0	0	0000	00016132
5887	13.42	-19.13	1363	6	644.12	644.12	639.18	0000000000	0000000000	0	0	0	0000	00015707
5888	1.34	-352.72	6700	1	645.12	645.12	639.17	0001001000	0001001000	0	3	0	0000	00015610
5888	3.14	45.51	16663	-21	645.12	645.12	640.18	0000000000	0000000000	0	0	0	0000	00016033
5888	3.41	50.57	7506	2	645.12	645.12	640.18	0000000000	0000000000	0	0	0	0000	00016105
5888	9.35	-274.36	1912	4	645.12	645.12	640.18	0000000000	0000000000	0	0	0	0000	00015464
5888	11.32	-54.54	8300	0	645.12	645.12	640.19	0000000000	0000000000	0	0	0	0000	00016132
5888	13.49	-19.03	1363	6	645.12	644.12	640.19	0000000000	0000000000	0	0	0	0000	00015707
5889	1.23	-359.32	6700	0	646.12	646.12	639.17	0001001000	0001001000	0	3	0	0000	00015610
5889	3.15	47.41	16491	-22	646.12	646.12	641.18	0000000000	0000000000	0	0	0	0000	00016033
5889	3.55	49.57	7506	1	646.12	646.12	641.18	0000000000	0000000000	0	0	0	0000	00016105
5889	9.73	-276.76	1912	3	646.12	646.12	641.18	0000000000	0000000000	0	0	0	0000	00015464
5889	11.30	-54.34	8300	0	646.12	645.12	641.19	0000000000	0000000000	0	0	0	0000	00016132
5889	13.47	-34.43	1425	13	646.12	646.12	641.19	0000000000	0000000000	0	0	0	0000	00015707
5890	1.13	-360.47	6700	0	647.12	647.12	647.20	0001011000	0001011000	0	3	0	0000	00015610
5890	3.37	44.22	16675	-18	647.12	647.12	642.20	0000000000	0000000000	0	0	0	0000	00016033
5890	3.53	41.53	7506	0	647.12	647.12	642.20	0000000000	0000000000	0	0	0	0000	00016105
5890	9.71	-274.57	1912	2	647.12	647.12	642.20	0000000000	0000000000	0	0	0	0000	00015464
5890	11.22	-54.39	8300	0	647.12	647.12	642.20	0000000000	0000000000	0	0	0	0000	00016132
5890	13.45	-42.93	1425	11	647.12	647.12	642.21	0000000000	0000000000	0	0	0	0000	00015707
5891	1.33	-361.57	6700	0	648.12	648.12	647.20	0001011000	0001011000	0	3	0	0000	00015610
5891	3.13	46.25	16631	-23	648.12	648.12	643.19	0000000000	0000000000	0	0	0	0000	00016033
5891	3.55	47.35	7506	0	648.12	648.12	643.19	0000000000	0000000000	0	0	0	0000	00016105
5891	9.53	-269.94	1912	1	648.12	648.12	643.19	0000000000	0000000000	0	0	0	0000	00015464
5891	11.23	-47.08	8800	0	648.12	648.12	643.19	0000000000	0000000000	0	0	0	0000	00016132
5891	13.44	-49.33	1418	9	648.12	648.12	643.19	0000000000	0000000000	0	0	0	0000	00015707
5892	0.93	-363.22	6700	0	649.12	649.12	647.20	0001011000	0001011000	0	3	0	0000	00015610
5892	3.19	48.95	16612	-20	649.12	648.12	644.19	0000000000	0000000000	0	0	0	0000	00016033
5892	3.57	57.36	7500	-1	649.12	649.12	644.19	0000000000	0000000000	0	0	0	0000	00016105
5892	9.56	-264.77	1906	1	649.12	649.12	644.19	0000000000	0000000000	0	0	0	0000	00015464
5892	11.27	-47.63	8800	0	649.12	649.12	644.19	0000000000	0000000000	0	0	0	0000	00016132
5892	13.42	-50.38	1418	9	649.12	649.12	644.19	0000000000	0000000000	0	0	0	0000	00015707
5893	0.93	-364.32	6700	0	650.12	650.12	647.20	0001011000	0001011000	0	3	0	0000	00015610
5893	3.10	46.75	16593	-20	650.12	650.12	645.18	0000000000	0000000000	0	0	0	0000	00016033
5893	3.58	55.66	7500	-1	650.12	650.12	645.18	0000000000	0000000000	0	0	0	0000	00016105
5893	9.49	-267.96	1906	0	650.12	650.12	645.18	0000000000	0000000000	0	0	0	0000	00015464
5893	11.25	-45.10	8300	0	650.12	650.12	645.18	0000000000	0000000000	0	0	0	0000	00016132
5893	13.40	-55.66	1375	1	650.12	650.12	645.18	0000000000	0000000000	0	0	0	0000	00015707
5894	0.73	-365.42	6700	0	651.12	651.12	647.20	0001011000	0001011000	0	3	0	0000	00015610
5894	3.12	51.40	16581	-19	651.12	651.12	646.19	0000000000	0000000000	0	0	0	0000	00016033
5894	4.73	55.11	7500	0	651.12	651.12	646.19	0000000000	0000000000	0	0	0	0000	00016105
5894	9.42	-259.05	1906	0	651.12	651.12	646.19	0000000000	0000000000	0	0	0	0000	00015464
5894	11.25	-40.92	8300	0	651.12	651.12	646.19	0000000000	0000000000	0	0	0	0000	00016132
5894	13.39	-55.66	1375	1	651.12	650.12	646.19	0000000000	0000000000	0	0	0	0000	00015707
5895	0.52	-370.70	6700	0	652.12	652.12	647.20	0001011000	0001011000	0	3	0	0000	00015610

81-25-B-3

FIGURE B-3. BCAS MESSAGE TYPE 10

END

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